Influence of Quadrapole and Hexa decapole deformation on Evaporation residue cross section

P.S.Damodara Gupta[1&2], H.C.Manjunatha[2$], T.Ganesh[2], N.Sowmya[1#],
L.Seenappa[1] and K.N.Sridhar[3]
[1]Department of Physics, Government college for Women, Kolar – 563101, INDIA
[2]Department of Physics, Rajah Serfoji Government College, Thanjavur-613005, Affiliated to Bharathidasan University, Tiruchirappalli,, INDIA
[1]Department of Physics, Government first grade college, Kolar – 563101, INDIA
*· * email: $manjunathhc@rediffmail.com and #sowmyaprakash8@gmail.com*

Introduction

In reaction dynamics effect of deformations and orientations has a major contribution[1]. The study of the fusion reaction of ^{16}O with deformed and spherical Sm reactions shows the importance of deformation in heavy-ion reactions [2]. In the side tip collision, the fusion reaction needs some extra energy than the fusion barrier[3]. The Sub-barrier fusion process is influenced by the deformations of both the projectile and target nucleus[4]. From the study of fusion cross sections calculated for ^{16}O on ^{184}W at sub-barrier energies, it is clear that in sub-barrier fusion for positive and negative quadrupole and hexadecapole moments respectively nuclei have larger cross sections [5].

Fusion and Evaporation residue (ER) cross sections are sensitive to quadrupole and hexadecapole deformations[6]. Furthermore, fusion cross sections of heavy ion reactions are found to be sensitive to hexadecapole moment. It is also observed that studies on deformation-dependent heavy ion fusion reactions which were used in the synthesis of superheavy elements. there is a need for study of influence of quadrupole deformation and hexadecapole deformation parameters. Hence in the present study we have systematically investigated the dependence of fusion reactions on deformation parameters.

In the present work, we have selected different projectile target combinations to synthesize the compound nucleus ^{220}Th. The fusion evaporation residue cross section for these projectile target combinations is evaluated using ASM[10] model and it is compared with experiments.

Theory

The evaporation-residue (ER) cross can be evaluated from the following equation [7]:

$$\sigma_{ER} = \sum_{J_C \geq 0} \sigma_{fus}(E_{cm}, J_C) P_{Surv}(E_C^*, J_C) \quad (1)$$

Where σ_{fus} is the fusion cross section is given as:

$$\sigma_{fus} = \frac{\pi}{k^2}(2J_C + 1) P_{fus}(E_{cm} J_C) \quad (2)$$

where k is wave number, P_{fus} is fusion probability and J_C is the total angular momentum of the compound system. P_{surv} is the survival probability of compound nuclei.

Results and Discussions

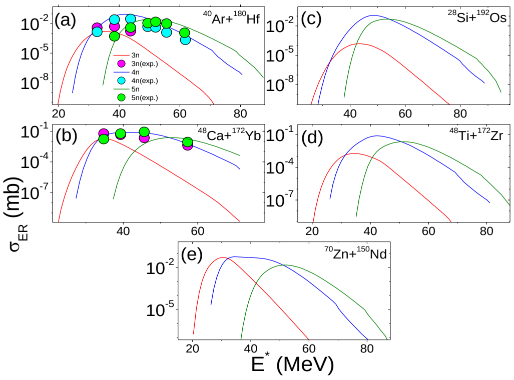

Fig. 1 Comparison of experimental evaporation cross sections [11,12] with calculated cross sections as a function of excitation energy for different reactions to synthesis the ^{220}Th.

From the previous researchers [1-9]it is clear that the fusion process dependence on the deformations of the projectile and target nuclei, change in the deformations affects on the ER cross sections. In the present work to study the quadruple and hexadecapole deformations effects on the ER cross section we analysed 5 projectile target combinations such as $^{40}Ar+^{180}Hf$, $^{48}Ca+^{172}Yb$, $^{28}Si+^{192}Os$, $^{48}Ti+^{172}Zr$ and $^{70}Zn+^{150}Nd$ to synthesis the compound nuclei ^{220}Th.

Fig.1(a) and fig.1(b) shows the comparison of the experimental [8,9] ER cross section with that of the present work for the reaction $^{40}Ar+^{180}Hf$ and $^{48}Ca+^{172}Yb$ respectively. Scattered symbols represent the experimental values and continuous plots for the calculated values, from this comparison, it is clear that calculated ER cross sections well agree with that of experimental values. fig.1(c), fig.1(d), and fig.1(e) show the variation of ER cross sections as a function of Excitation energy E^* for 3n, 4n and 5n evaporation channels for the reactions $^{28}Si+^{192}Os$, $^{48}Ti+^{172}Zr$ and $^{70}Zn+^{150}Nd$.

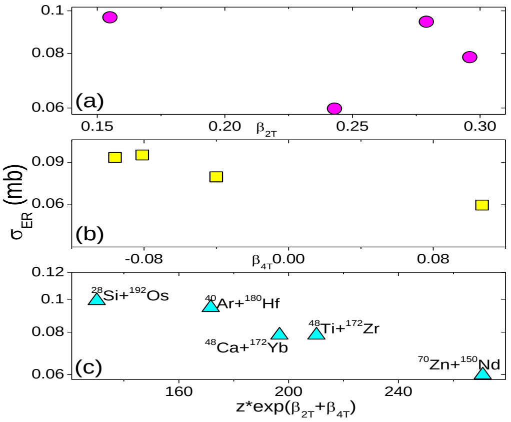

Fig. 2 (a) Variation of ER cross-section at optimal energy as a function of quadrupole deformation of target nuclei. (b) Variation of evaporation residue cross section at optimal energy as a function of hexadecapole deformation of a target nuclei.(c)Variation of σ_{ER} at optimal energy as a function of $z^*\exp(\beta_{2T}+\beta_{4T})$.

To explore the influence of quadrupole and hexadecapole deformations, we have plotted ER cross sections as a function of quadruple deformations (fig.2(a)) and hexadecapole deformations (fig.2(b)). From these figures it is observed that there are no systematic variations of σ_{ER} with β_{2T}, however, σ_{ER} was found to decrease with an increase in β_{4T}. Furthermore, the product of the entrance channel like coulomb interaction parameter (z) and deformation parameters will influence the ER cross sections. the variation of σ_{ER} with $z*\exp(\beta_{2T}+\beta_{4T})$ is found to be almost systematic hence we may conclude that the combination of entrance channel parameters and deformation parameters is required to study the heavy ion fusion reactions.

Summary

The significance of quadrapole deformation and hexadecapole deformation on heavy ion fusion reactions leads to synthesis the compound nucleus ^{220}Th is studied. Influence of hexadecapole on the heavy ion fusion is larger than that of quadrapole deformation. The combination of deformations on entrance channel parametres are required to study complete information of heavy ion fusion.

References

[1] Deepika Jain, Raj Kumar and Manoj K.Sharma, Nucl. Phys. A **915**, 106 (2013).

[2] Y. Eisen, S. Kaplanis, D. Pelte, U. Smilansky, and I. Tserruy, Phys. Rev. Lett. **41**, 465 (1972).

[3] S.Mitsuoka, H.Ikezoe, K.Nishio, K.Satou and J.Lu, Phys. Rev. C **65**, 054608 (2002).

[4] V.V.Sargsyan, G.G.Adamian, N.V.Antonenko, W.Scheid and H.Q.Zhang, Phys. Rev. C **84**, 064614 (2011).

[5] M.J.Rhoades Brown and V.E.Oberacker, Phys. Rev. Lett. **50**, 1435 (1983).

[6] M. Dasgupta, D. Hinde, N. Rowley, and A. Stefanini, Annu. Rev. Nucl. Part. Sci. **48**, 401 (1998).

[7] H.C.Manjunatha, L.Seenappa, P.S.Damodara Gupta, et al., Phys. Rev. C **103**, 024311 (2021).

[8] H.C.Manjunatha, P.S.Damodara Gupta, N.Sowmya, et al., Phys. Rev. C **105**, 044605 (2022).

[9] H.C.Manjunatha, P.S.Damodara Gupta, N.Sowmya, et al., Phys. Rev. C **104**, 024622 (2021).

[10] Hongliang Lü , Anthony Marchix, Yasuhisa Abe and David Boilley, Comput. Phys. Commun. **200**, 381 (2016).

[11] D.Vermeulen, H.G.Clerc, C.C.Sahm, K.H.Schmidt, J.G.Keller et al.,, Z. Phys. A **318**, 157 (1984).

[12] C.C.Sahm, H.G.Clerc, K.H.Schmidt, et al.,, Nucl. Phys. A **441**, 316 (1985).