Study of the dependence of survival probability on neutron shell closure in heavy mass region (A~200)

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Introduction

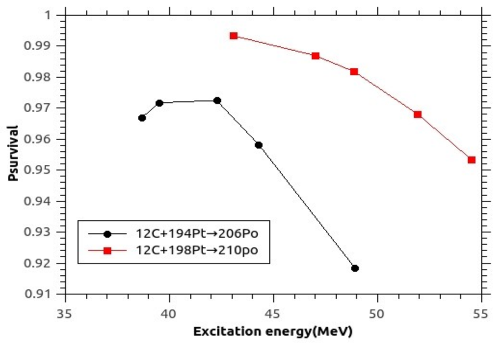
Nuclear reaction dynamics in the mass region A=200 is an area of utmost important in the nuclear physics research field. When the two heavy ion scatter off each other with very small impact parameter and sufficient energy to overcome the Coulomb barrier there may be a complete fusion of the projectile with the target, results in the formation of a compound nucleus. This compound nucleus formed with very high angular momentum and energy rapidly decays to its ground state by emission of some light particles such as proton or neutrons and/or some gamma rays or by fission. Usually in the compound nuclear mass 200 region fission and ER formation are the two competing channels. The fate of a compound nucleus weather it will survive fission to form a heavy evaporation residue (ER) depend on the energy, angular momentum, spin etc of the compound nucleus and also on the entrance channel properties. In this work a systematic analysis of the survival probabilities of the compound nuclei (A=200 to 212) formed through different entrance channels have been analyzed with a view to understand the prominent decay mode in the mass 200 region and also to study the dependence of the survival probability ($P_{survival}$) on the properties of the compound nucleus and the reaction parameters.

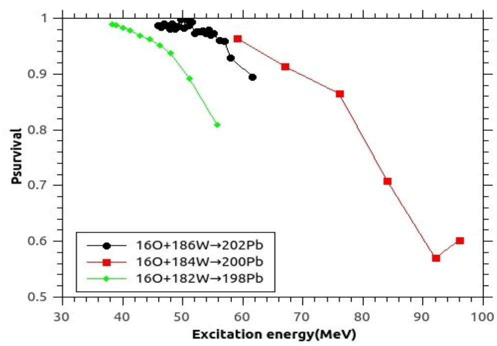
Result and discussion

The total ER cross section can be written as

$$\sigma_{ER}(E_{cm})=\sigma_{capture}(E_{cm})\, P_{CN}(E_{cm})\, P_{survival}(E_{cm}) \quad [1]$$

where $\sigma_{capture}$ is the capture cross-section for the formation of the di-nucleus system and E_{cm} is the entrance channel kinetic energy in the centre of mass. P_{CN} is the probability of complete fusion of the dinuclear system to form the compound nuceus, $P_{survival}$ is the survival probability of the CN to form ER at a given excitation energy, which is determined by the competition between fission and evaporation of the excited compound nucleus. It is calculated as the ratio of ER cross section to the fusion cross section. Here the complete fusion cross section is used for the calculations, so there will be no contribution from non compound nuclear processes like quasi fission, pre - equilibrium fission in the survival probability. Hence the analysis clearly gives information about the competition between fission and ER formation in the 200 mass region.





In the case of ^{12}C induced reaction the survival probability is more for ^{210}Po than ^{206}Po due to its neutron magicity (N=126). For the O induced reactions on W the survival probability is maximum for 200Pb in the excitation energy range 50 to 60MeV after that it start to decrease.

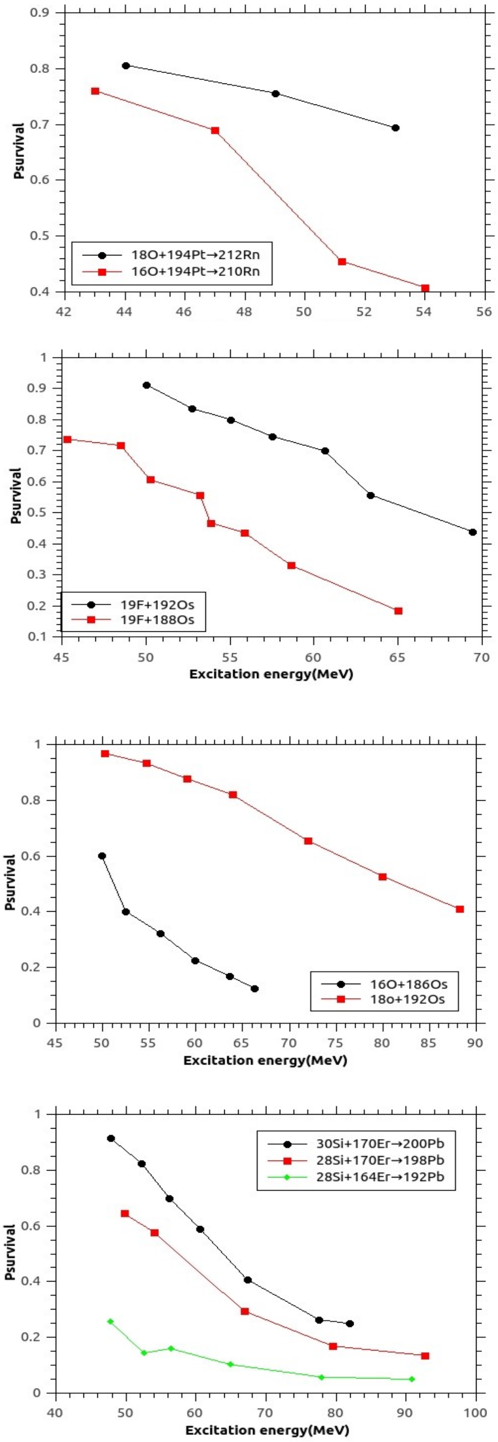


Fig 1- 6. The survival probabilities of the CN formed through different entrance channel.

For the compound nuclei ^{210}Rn and ^{212}Rn, the survival probability is more for ^{212}Rn compared to the other due its neutron magicity(N=126), but the maximum value (0.8) is reduced due to its increased fissility of the compound nucleus. In the case of ^{207}At and ^{211}At (N=126) also the effect of magicity is reflected. In the case of Si induced reactions, though the compound nucleus formed is a magic nucleus, the survival probability is small and is much different from that of the same compound nucleus formed through different entrance channels. 192Pb has a neutron shell closure and it has the smallest survival probability.

Conclusion

The survival probability is decreasing with increase in the excitation energy due to the decreases in the fission barrier as the excitation energy increases. For the same compound nucleus with different neutron number survival probability is more for nuclei with large (N/Z). As the compound nucleus become more heavier the maximum value of survival probability is decreasing except for the neutron shell closed nuclei. Since the neutron separation energy is more for shell closed nuclei survival probability is more for such nuclei. There is a notable difference in the survival probability of the same compound nucleus formed through different entrance channels as the system become more symmetric. Thus closed shell nuclei are more stable against fission compared to the neighboring non closed shell nuclei for asymmetric systems and for the symmetric systems $P_{survival}$ is more for the non closed shell nuclei.

Reference

[1] Yu.Ts. Oganessian and Y.A. Laza Treatise on Heavy-Ion Science by D.A. Bromley (Plenum, 1985), p.3.