Influence of nucleon density distribution in nucleon emission probability

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Introduction

Different decay modes are observed in heavy ion reactions at low to intermediate energies. It is interesting to study total neutron emission in these reactions which may be contributed by all / many of these decay modes. In the energy range of few tens of MeV per nucleon evaporation model fails to explain a large part of the double-differential cross section. Our earlier model, based on two-body scattering kinematics had been tested for a few systems [1, 2]. It was observed that the model was successful to explain energy-angle distribution of neutrons fairly well. But the back angle emission was overpredicted. The model takes into account effect of nuclear excitation on the motion of the nucleons and considers conservation of energy and linear momentum during relaxation of the system. But in heavy ion reactions angular momentum brought in by the projectile plays an important role. Secondly the mean field of the constituent nucleons influences the emission from the composite system. These effects have not been taken into account in our earlier work. In an attempt to understand the importance of mean field and the entrance channel angular momentum, we study their influence on the emission probability of nucleons in heavy ion reactions in this work. This study owes its significance to the fact that once population of different states are determined, emission probability governs the double differential neutron yield.

Method of calculation

Glauber model analysis of total reaction cross section gives an estimate of the matter radii. The density distribution obtained from relativistic mean field theory shows an asymptotic behavior with some local fluctuation at the centre. This form of density distribution developed by Gambhir et al. [3] has been used in this work to determine the nucleon density distribution for the composite system formed in the reaction ^{20}Ne+^{165}Ho. Mean free path for the interacting nucleons is calculated as $\lambda_m = \dfrac{1}{\rho\sigma}$ where ρ is the matter density at the point of interaction ‘r’. The point of first two-body interaction is determined from the entrance channel parameters for different values of *l*. σ is the in medium nucleon-nucleon collision cross section and its value is taken from literature [4]. The collision rate at different nucleon energy is calculated from the nucleon velocity and the mean free path. Emission probability is then determined from the competition of the collision rate and emission rate. For the subsequent two-body collisions, the point of interaction was taken to be one mean free path away from the previous interaction.

Results and discussion

We have shown the average nucleon density distribution for ^{185}Ir (^{20}Ne+^{165}Ho) in figure 1. Collision rates and subsequently emission probabilities at different emission energies have been calculated using these density distributions. Nucleon emission probability calculated using this prescription is shown in fig. 2 for *l* = 1, 10, 20 and 30. In the earlier form of the heavy ion reaction model and the code HION developed by us emission probability was determined using an empirical expression for the total two-body collision rate given by Blann [5]. We have also compared the calculated emission probabilities from this work with that used by Blann. This comparison is shown in fig. 3.

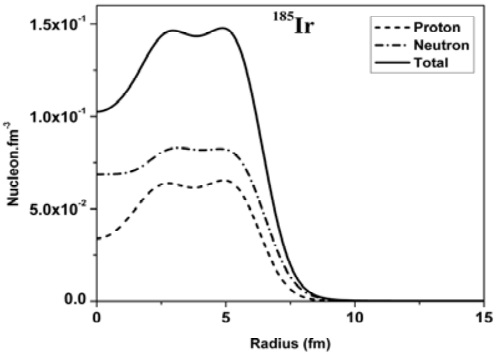

Fig. 1 Average nucleon density distribution for ^{20}Ne+^{165}Ho system

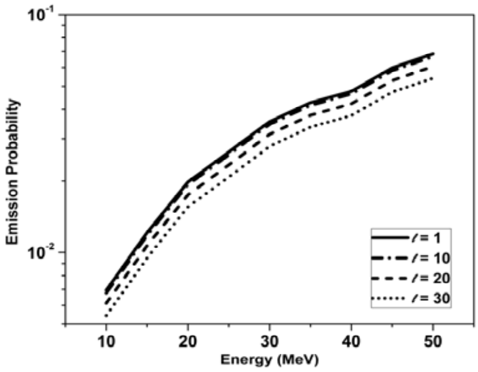

Fig. 2 Comparison of emission probability

From figure 1 we see that proton density at the centre is almost half of its maximum value while neutron density at the centre is ~83% of its maximum value. Both these densities show a dip between the two maxima. From fig. 2 it is observed that at a given emission energy emission probability decreases by about 22% from *l* = 1 to *l* =30. The rate of decrease is same for all emission energies and is attributed to the slight increase in the nucleon density at the point of interaction. For a given *l* and corresponding r the emission probability increases monotonically with energy. This is expected as we are studying the probability of emission from a state already populated at energy E (sum of emission energy ε and binding energy B of the neutron). Figure 3 shows that, emission probability obtained using Blann's prescription is larger by almost one order of magnitude at low emission energies than that obtained in the present work. At higher neutron energy the disagreement decreases but the present value is still lower. This observation needs to be investigated as it may resolve the overprediction at back angle obtained for some systems investigated in our earlier work.

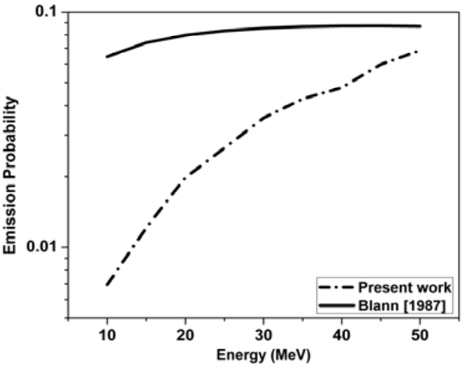

Fig. 3 Comparison of emission probabilities with present work and Blann's prescription

Conclusion

Two-body collision rates are calculated from semi-phenomenological model for nucleon densities and published in-medium nucleon-nucleon cross sections. Emission probabilities calculated using these results show steep slope with energy at low emission energies. Emission probabilities thus obtained are also much lower, particularly at small emission energies, than the results of the earlier work of Blann [5]. This may play an important role in predicting neutron emission from heavy ion reactions which showed overprediction at back angles. Nucleon emission probability calculated using our formalism also shows a decrease with increasing impact parameter.

References

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