Analysis of ER and fission in decay of ^{210}Rn* formed in ^{16}O + ^{194}Pt reaction

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Introduction

Heavy ion induced reactions are of immense interest as they hold the probability of non compound nucleus component in addition to the usual compound nucleus decay. Generally, the compound nucleus formed in heavy ion collision decays by emitting different fragments/clusters. For the heavy nuclear system like ^{210}Rn*, emission of both evaporation residue (ER) and fission are equally probable. The comparative analysis of the two decay processes would be of great interest for better understanding of dynamics involved. In recent experiment [1], the ER cross-sections for the decay of ^{210}Rn* have been measured over a wide range of energies. Along with the experimental ER cross-sections, the complete fusion cross-sections calculated by using CCFULL are also available. The fission cross-sections are estimated by subtracting the evaporation residue cross-sections from CCFULL calculated complete fusion cross-sections. In the present work, the decay of ^{210}Rn* is studied using the dynamical cluster decay model (DCM) [2] in reference to data of [1]. The ER as well as fission cross-sections are calculated by independent as well as simultaneous choice of neck length parameter "ΔR", and the calculated cross sections are found to be in agreement with data of [1].

The Model

The DCM [2] based on the well known quantum mechanical fragmentation theory (QMFT) uses the collective coordinates of mass asymmetry $\eta = \frac{A_1 - A_2}{A_1 + A_2}$ and relative separation R, to define the compound nucleus decay cross sections in terms of the partial waves as;

$$\sigma = \frac{\pi}{k^2} \sum_{l=0}^{l_{max}} (2l+1) P_0 P; \qquad k = \sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}}$$

with μ as the reduced mass and, l_{max}, the maximum angular momentum, fixed for the light particle cross section $\sigma_{LP} \to 0$. P_0, the preformation probability, is the solution of stationary schrodinger equation in mass asymmetry coordinate η given as

$$P_0 = \mid \psi^{\nu=0}(\eta(A_i)) \mid^2 \sqrt{B_{\eta\eta}} \frac{2}{A_{CN}}$$

For the non compound nucleus component, in the form of quasi fission qf, the preformation probabiity is taken as P_0=1. P is the WKB penetrability of preformed fragments in R-motion. In DCM, the emission of ER, intermediate mass fragments (IMF) and fission fragments is treated using collective clusterization process. The only parameter of the model is the temperature dependent neck length parameter ΔR(T), defining the first turning point $R_a = R_1(\alpha_1, T) + R_2(\alpha_2, T) + \Delta R(T)$ for the penetration of preformed fragments.

Calculations and results

The decay of ^{210}Rn* nuclear system formed in ^{16}O + ^{194}Pt reaction channel is investigated using DCM. The ER and fission cross sections are fitted separately by adjusting the neck length parameter (ΔR). We refer this choice as independent fitting. DCM results are in agreement with the available data at all energies except at highest two energies for fission. This disagreement at the higher energies may call the non compound nucleus contribution,

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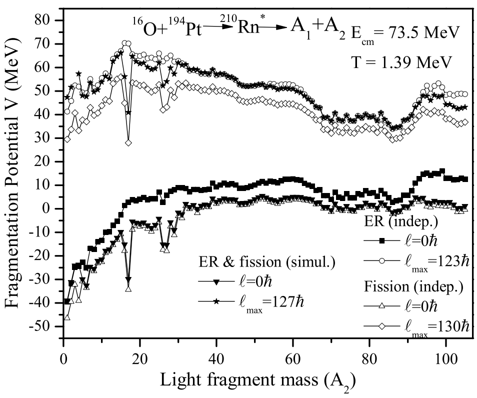

FIG. 1: Shows the fragmentation potentials $V(R,\ell)$ as a function of A_2 for the decay of $^{210}Rn^*$ formed in $^{16}O+^{194}Pt$ reaction channel at $E_{c.m.}$=73.5 MeV for independent as well as simultaneous fitting of ER and fission processes at extreme values of angular momentum for β_2 deformed choice.

such as quasi fission (qf). To confirm this, we tried further by simultaneously fitting the ER and fission process at the highest energy but again the calculated fission cross sections were lower than [1]. Therefore possibility of qf at highest incident energies seem evident independent of choice of fitting. Henceforth, the qf component is worked out by taking P_0=1, and $\sigma_{qf}\approx$170 mb is predicted at ΔR=1.12 fm and 1.19 fm respectively for independent and simultaneous choice of neck length parameter. It is of further interest to have comparative analysis of fragmentation path for independent as well as simultaneous fitting of two decay processes i.e evaporation residue (ER) and fission. Fig.1 shows the fragmentation potential as a function of light mass fragment (A_2) for the decay of $^{210}Rn^*$ for independent and simultaneous fitting of ER and fission processes at extreme ℓ-values. One can observe from Fig.1 that for independent choice of fitting, the fragmentation potential show more structure for the fission case whereas it is relatively smooth for the ER. However, for simultaneous fitting, the potential energy surfaces are similar to that for (independent) fission case with slight variation in magnitude. The presence of certain minimas suggest the dominance of these fragments in the decay path. Important point to note here is that the fragment distribution in fissioning region remains asymmetric for all the three choices of neck length parameter. For fission cross sections, the fragments in the range A_2=68-91 contribute independent of the choice of fitting. The $\triangle$R is observed to be relatively higher for the simultaneous fitting ($\triangle R_{ER}$=1.642fm and $\triangle R_{fission}$=0.99fm) as compared to independent ($\triangle R_{ER}$=1.574fm and $\triangle R_{fission}$=0.90fm) addressal of ER and fission. The same is true for the qf case. For either of the fitting procedure, the $\triangle$R for ER is highest followed by qf and fission processes.

Summarizingly, the fragmentation profile of $^{210}Rn^*$ via ER and fission does not depend much on the type of fitting procedure. The overall structure as well as contributing fragments towards fission remain same for simultaneous and independent choice of neck length parameter, however the $\triangle$Rs are relatively larger for simultaneous choice. The non compound nucleus contribution in the form of quasi fission is predicted at highest two energies.

Acknowledgments

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