Probing shell effects in the reaction dynamics of low energy heavy ion collisions populating different isotopes of Rn

Rupinder Kaur[1,2], BirBikram Singh[2],* Mandeep Kaur[2], Maninder Kaur[3], Varinderjit Singh[3], B.S. Sandhu[1], and Raj K. Gupta[4]

[1]*Department of Physics, Punjabi University, Patiala-147002, India.*
[2]*Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib-140406, India.*
[3]*Department of Physical Sciences, I.K.G. Punjab Technical University, Kapurthala-144603, India. and*
[4]*Depratment of Physics, Panjab University, Chandigarh-160014, India.*

Introduction

Heavy ion fusion reactions around Coulomb barrier are a rich source of information about properties of compound nuclei (CN) and have been a topic of extensive experimental and theoretical research. The CN resulting from these reactions are sensitive towards the entrance channels aspects such as equilibration in energy, mass, angular momentum and nuclear structure, etc. For the shell correction energies, which are the microscopic component of fission barrier, there is a great surmise that shell closure at Z=82 and N=126 favors survival probability of CN against fission [1]. However, recent experimental studies have indicated the absence of extra stability of shell closed nucleus [2]. In the present study, an attempt has been made to understand such aspects using CN $^{210,212,214,216}Rn^*$ formed in the low energy reactions $^{16,18}O+^{194,198}Pt$ around the Coulomb barrier. This study has been made within the quantum mechanical fragmentation theory (QMFT)-based Dynamical cluster-decay model (DCM) [3] in which the CN decays into light particles (LPs), intermediate mass fragments (IMFS), heavy mass fragments, near-symmetric and symmetric fission (nSF, SF). Quite interestingly, all of these decay modes are treated on the same footing as dynamical collective mass motion of preformed fragments through the potential barrier.

It is relevant to mention here that collective mass motion of the fragments is quantified in terms of the preformation probability P_0 which carries the important information about the nuclear structure of the decaying nucleus. Subsequently, penetration probability P of the outgoing fragments across the potential barrier is calculated. These two significant quantities P_0 and P are then used to calculate the cross section for particular decay channel.

In the present work, we intend to see the effects of neutron shell closure in compound nucleus $^{212}Rn^*$ (N = 126) and its neighbouring isotopes $^{210,214,216}Rn^*$, having N = 124, 128, 130, respectively, on their decay. The calculations for the fragmentation potential and P_0 have been made for the decay of CN $^{210,212,214,216}Rn^*$ at E^*=49 MeV. In DCM, the neck length parameter ΔR is the only free parameter of DCM, which is fitted to calculate LPs or evaporation residues (ER) cross section σ_{ER} and fusion-fission (FF) cross section σ_{FF} in decay of CN under study, for which the experimental data is available [1, 4].

Methodology

The DCM [3], worked out in terms of collective co-ordinates of mass (and charge) asymmetries, for ℓ-partial waves, gives the compound nucleus decay cross-section as

$$\sigma = \frac{\pi}{k^2}\sum_{l=0}^{l_{max}}(2l+1)P_0P; \qquad k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \tag{1}$$

where, $\mu = [A_1A_2/(A_1+A_2)]m$ is the reduced mass, with m as the nucleon mass and ℓ_{max} is the maximum angular momentum. P is penetrability of interaction barrier (of the preformed clusters with preformation probability P_0), calculated as the WKB tunneling probability, around the Coulomb barrier.

*Electronic address: birbikramsingh@sggswu.edu.in

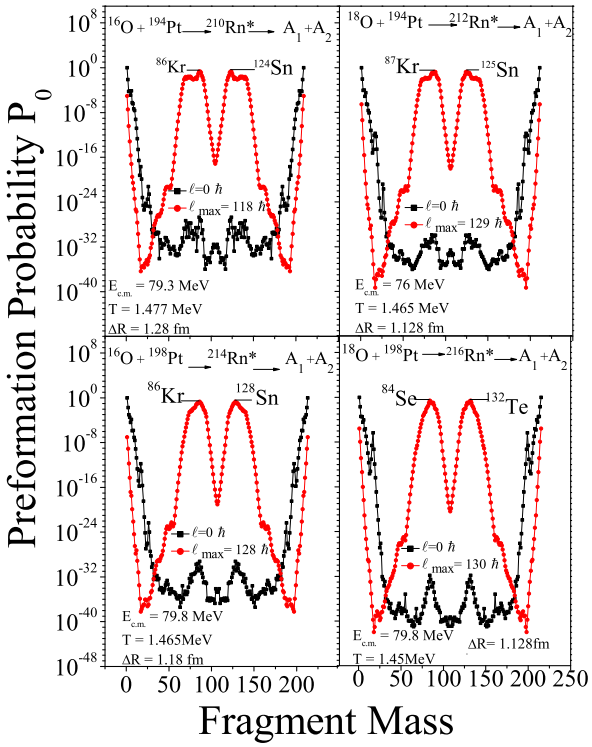

FIG. 1: P_0 profile for the decay of CN $^{210,212,214,216}Rn^*$ at $\ell = 0$ and ℓ_{max} having similar $E^*_{CN} \sim 49$ MeV.

Calculations and Discussions

Fig. 1 (a-d) presents the calculated P_0 of fragments in the decay of CN $^{210,212,214,216}Rn^*$ at E^*_{CN}=49 MeV and, $\ell = 0$ $\hbar$ and respective ℓ_{max}-values. Interestingly, these calculations reveal that among the FF fragments, most significant minima exist for the fragment(s) $^{86,87,86}Kr$ and its complimentary fragment(s) $^{124,125,128}Sn$ having proton shell closure Z = 50, respectively, in the decay of CN $^{210,212,214}Rn^*$, having highest P_0 for the FF fragments, particularly at the ℓ_{max}-values. Please note that for ^{86}Kr neutron shell closure is N = 50. It is important to point out here that for these nuclear systems the neutron shell closure for the compound nucleus $^{212}Rn^*$ is N = 126 and, its neighbouring isotopes $^{210,214}Rn^*$ are having N = 124 and 128, respectively, i.e., closer to the N = 126 shell closure. However, in the case of compound nucleus $^{216}Rn^*$ N = 130 which is away from the N = 126 shell closure and results in neighborhood of deformed magic Z = 38, highly preformed fragments ^{84}Se and its complimentary heavy fragment ^{132}Te which is also next to magic number Z = 50.

Moreover, the P_0 value for the LPs (A≤4) for the CN $^{210,212,214,216}Rn^*$ is in competition with the FF fragments at the respective ℓ_{max}-values. These preliminary results are quite motivating to study the complete comparative dynamics of CN $^{210,212,214,216}Rn^*$.

References

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