Influence of magicity Z = 82 in the decay of compound nuclei A ∼ 200

Sarbjeet Kaur[1,*] BirBikram Singh[1,†] and S. K. Patra[2]
[1] *Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib-140406, India and*
[2] *Institute Of Physics, Sachivalya Marg, Bhubhaneswar-751005, India*

Introduction

A number of macroscopic properties of nuclei could be understood in terms of the of Gamow's liquid-drop model [1]. However, limitations of this model to explain microscopic features, e.g., existence of magic nuclei (specific proton or neutron numbers that give additional stability to the nucleus), led to the development of the nuclear shell model by M. G. Mayor and J. H. Jensen, in 1949 [2]. Since then, effects of magic numbers on nuclear reaction dynamics has been a topic of great interest. Most significantly, synthesis of superheavy nuclei have been hypothesized by the prediction of the existence of closed shells beyond the heaviest doubly magic nucleus found in nature [3]. Moreover, effects of neutron shell closures N = 126, has also been explored to investigate the decay of compound nuclei (CN) [4], within the quantum mechanical fragmentation theory based Dynamical Cluster Decay Model (DCM) [4, 5]. The study revealed that the most prominent fusion-fission fragments for the decay of CN under study are having neutron-proton counts closer to the magic numbers.
Here, we have extended our previous work [6] of investigations of the effects of magicity Z = 82 in the decay of CN $^{194}Hg^*$, $^{200}Pb^*$, $^{203}Bi^*$ and $^{207}At^*$ formed in ^{19}F + ^{175}Lu, ^{19}F + ^{181}Ta, ^{19}F + ^{184}W and ^{19}F + ^{188}Os reactions, respectively, at different E_{lab} values. We have calculated the light particles cross sections (σ_{LPs}) for all the four reactions at different energies, leading to CN with A ∼ 200, in reference to the available experimental data [7]. In DCM, the collective fragmentation potential is calculated within Strutinsky macro-microscopic method and empirical shell corrections are taken from Myres and Swiatecki, to subsequently estimate the cross sections for the penetrating collectively clusterized/preformed fragments across the scattering potential. In the following sections, methodology followed for the work is given, briefly, along with results and discussions of the presented calculations.

*Electronic address: sarbjeetsangha13@gmail.com
†Electronic address: birbikramsingh@sggswu.edu.in

Methodology

The dynamical cluster decay model (DCM) [4, 5] of Gupta and collaborators is based on the collective coordinates of mass (and charge) asymmetries $\eta_A = \frac{A_1-A_2}{A_1+A_2}$ (and $\eta_Z = \frac{Z_1-Z_2}{Z_1+Z_2}$) and relative separation coordinate R with multipole deformations $\beta_{\lambda i}$ (λ=2,3,4... and i=1,2) and orientations θ_i of two fragments (i = 1, 2). In terms of these coordinates, we define the compound nucleus decay cross-section for ℓ partial waves as

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

where, μ is the reduced mass with m as nucleon mass and ℓ_{max}-value is the maximum angular momentum, fixed for the vanishing of the light particles cross-section, i.e. $\sigma_{LPs} \rightarrow 0$. P_0, the preformation probability, refers to η-motion and P, the penetrability, to R-motion, both dependent on angular momentum ℓ and temperature T.
P_0 is is obtained by solving a stationary Schrödinger equation in mass fragmentation coordinate and contains the structure information of the system and its decaying fragments. Once the clusters/fragments are preformed, their penetration probability P across

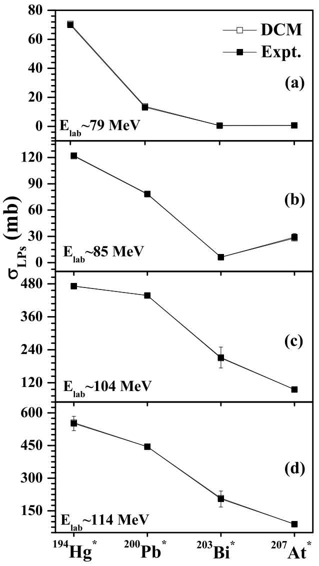

FIG. 1: The DCM calculated σ_{LPs} as a function of increasing Z of CN and their comparison with the experimental data, at the different E_{lab} values.

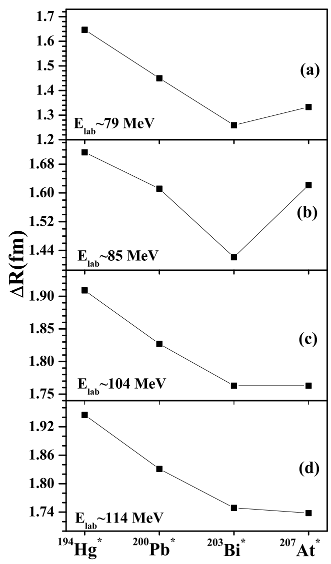

FIG. 2: Same as Fig. 1 but for ΔR.

the interaction barrier is calculated by using the WKB approximation.

Calculations and Discussions

Fig. 1 (a-d) shows the DCM calculated σ_{LPs} along with experimental data for the four reactions under study at four different energies. The DCM calculated σ_{LPs} show good agreement with experimental data. We have reported in our previous work [6], the preformation profiles of the favoured fragments in the decay of CN ^{194}Hg*, ^{200}Pb*, ^{203}Bi* and ^{207}At* at $E_{lab} \sim 85MeV$. We observed that for CN ^{194}Hg*, ^{200}Pb* and ^{203}Bi* LPs are strongly preformed, comparatively . However, the compound nucleus ^{207}At* shown to have weakly preformed LPs in comparision to asymmetric fragments, perhaps due to it's Z = 85 being away from the proton shell closure Z = 82. The σ_{LPs} is more for Z = 82 and around 82 CN i.e. in these systems there are less chances of fission, comparatively.

These results are also quite evident from Fig. 1 (a-d) which also includes the variation in the values of σ_{LPs} with increasing E_{lab} values. We see that σ_{LPs} decreases with increasing Z values of CN except at $E_{lab} \sim 85MeV$ (Fig. 1 (b)). Here, we find that there is rise in the value of σ_{LPs} for ^{207}At* in comparison to ^{203}Bi* (Fig. 1 (b)). However, for rest of the E_{lab} values σ_{LPs} decreases with increasing Z values of the CN. The DCM fitted ΔR values also reflect these results in Fig. 2 (a-d) for the corresponding CN systems as well as the energies. Here also we find the rise in the value of ΔR for compound nucleus ^{207}At*, not only at $E_{lab} \sim 85MeV$ (Fig. 2 (b)) but also at $79MeV$ (Fig. 2 (a)). The further investigation of these results is called for. Work is in progress.

References

[1] E. Rutherford, G. Gamow, *et. al.*, Proc. Roya. Soc. A **123**, 386 (1929).

[2] M. G. Mayer, Phys. Rev. **74**, 235 (1948); O. Haxel, J. H. D. Jensen, *et. al.*, Phys. Rev. **75**, 1766 (1949).

[3] A. Sobiczewski, F. A. Gareev, *et. al.*, Phys. Lett. **22**, 500 (1966).

[4] R. Kaur, B.B. Singh, *et. al.*, Proc. of the DAE Symp. on Nucl. Phys. **62**, 632 (2017).

[5] B.B. Singh, M. K. Sharma, *et. al.*, Phys. Rev. C **77**, 054613 (2008); M. Kaur, *et. al.*, Phys. Rev. C **92**, 024623 (2015); Nucl. Phys. A **969**, 14 (2018); M. Kaur, *et. al.*, Phys. Rev. C **99**, 014614 (2019).

[6] S. Kaur, M. Kaur *et. al.*, Proc. of the DAE Symp. on Nucl. Phys. **63**, 472 (2018).

[7] S. Nath, P. V. Madhusudhana Rao, *et. al.*, Phys. Rev. C **81**, 064601 (2010).