Study of light charged particle emission from Pb-isotopes formed in n-induced reactions

Amandeep Kaur[1],* Kirandeep Sandhu[2], and Manoj K. Sharma[3]

[1,3] *School of Physics and Materials Science, Thapar University, Patiala-147004, PUNJAB and*

[2] *Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib 140406, PUNJAB*

Introduction

Pb has always been the most important nucleus which is exclusively explored due to its doubly magic shell closure. Various endeavors involve the use of heavy ions as projectiles to investigate the decay of Pb isotopes. Simultaneously n-beams have also been used to explore the dynamics governing the various decay patterns of heavy mass compound systems. The reactions involving amalgamation of neutrons with Pb-isotopes play significant role not only in the domain of experimental studies but also provide the theoretical insight to investigate the nuclear structure and related dynamics. In view of this an attempt has been made to study the light charged particle emission from ^{209}Pb* and ^{207}Pb* formed in n-induced reactions over incident beam energy E_{beam}=14-21 MeV in reference to [1]. The dynamics involved within the decay of ^{209}Pb* via p-emission and ^{207}Pb* via α-emission are explored using the Dynamical Cluster-decay Model(DCM)[2] and the cross-sections have been addressed adequately by optimizing the neck-length parameter(ΔR).

It is relevant to mention here that the DCM based calculations involve the liquid drop binding energies of Seeger [3] and various potential terms which include the mass dependent radius terms R(A). In the present work we intend to explore the relative effect of charge-dependent radius term R(Z)[4], within DCM based calculations. The relative effect of R(A) and R(Z) is explored in terms of fragmentation structures of ^{209}Pb* and ^{207}Pb* and consequently from the modifications in the barrier characteristics such as barrier height V_B for the decay ^{209}Pb$^*\rightarrow^{208}$Tl+p and ^{207}Pb$^*\rightarrow^{203}$Hg+α.

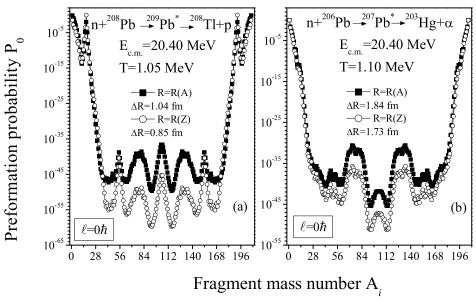

FIG. 1: (a) Variation of preformation probability as a function fragment mass (b) Variation of preformation probability summed-up for A_2=100-112 as a function of angular momentum for hot and cold configurations.

The Dynamical Cluster-decay Model (DCM)

Using the decoupled approximation, in DCM[2] the cross-sections are given as:

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

The preformation probability (P_0) refers to η-motion while the penetrability (P) refers to R-motion. The structural effects in P_0 are incorporated via fragmentation potential:

$$V_R(\eta,T) = -\sum_{i=1}^{2}B_i(A_i,Z_i,T) + V_C(R,Z_i,\beta_{\lambda i},\theta_i,T) + V_P(R,A_i,\beta_{\lambda i},\theta_i,T) + V_\ell(R,A_i,\beta_{\lambda i},\theta_i,T) \quad (2)$$

The mass and charge-dependent radius[4], which goes as an input in above expression, reads as:

$$R_{0i}(A) = \left[1.28A_i^{1/3} - 0.76 + 0.8A_i^{-1/3}\right] \quad (3)$$

*Electronic address: adeepkaur89@gmail.com

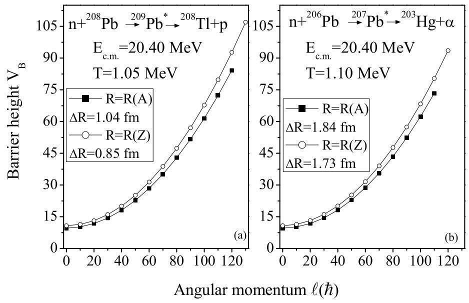

FIG. 2: (a) Variation of preformation probability as a function fragment mass (b) Variation of preformation probability summed-up for A_2=100-112 as a function of angular momentum for hot and cold configurations.

and

$$R_{0i}(Z) = [1.76 Z_i^{1/3} - 0.96] \qquad (4)$$

Results and discussions

The present work is confined to study the dynamics involved in the decay of Pb-isotopes where the compound systems $^{209}Pb^*$ and $^{207}Pb^*$ decay via p-emission and α-emission respectively and the experimental cross-sections are addressed nicely through collective clusterization approach of DCM. In addition to this, the role of charge-dependent radius R(Z) within DCM based calculations is also investigated. It should be noted that the use of R(Z) tends to fit the cross-sections at lower values of ΔR as compared to R(A). The effect of replacement of mass dependent radius term R(A) with R(Z) on the overall fragmentation structure can be seen from the preformation curve plotted in Fig.1. Here, preformation probability P_0 is plotted as a function of fragment mass number A_i for the decay of (a)$^{209}Pb^*$ and (b) $^{207}Pb^*$ at common center of mass energy $E_{c.m.}$=20.40 MeV and ℓ=0$\hbar$. It is clearly seen that by replacing R(A) with R(Z) no significant variation in the fragmentation structure is observed but significant changes in magnitude are observed in the heavy mass fragment(HMF) and fission region for both the compound systems $^{209}Pb^*$ and $^{207}Pb^*$. Although the light charged particle region almost overlaps for either choice of the chosen radii. So it may be concluded that the choice of charge dependent radius term may play significant role in the dynamics of reactions involving HMF or fission fragments in decay channel. In addition to this, the effect of the interchange of R(A) with R(Z) on barrier characteristics such as barrier height V_B is also investigated and the barrier height V_B is plotted as a function of angular momentum for the decay (a)$^{209}Pb^* \rightarrow ^{208}Tl$+p and (b)$^{207}Pb^* \rightarrow ^{203}Hg+\alpha$ at common $E_{c.m.}$=20.40 MeV for the use of both radius terms in Fig.2. It is clear from the Fig.2, that the barrier height V_B increases with increase angular momentum for both the choice of radius terms R(A) as well as R(Z). It has been observed that at lower ℓ-values, the barrier height is almost same for both the choices of radius, however at higher ℓ-values, the use of R(Z) shows an enhancement in the barrier height. Since light charged particle emission is favored at lower ℓ-values so it can be concluded that for the addressal of light charged particle emission, use of R(Z) does not show significant effect on fragmentation structure as well as barrier height but seems to play significant role in the dynamics of HMF and fission fragments.

Acknowledgement

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References

[1] V. Semkova et al. Phys. Rev. C **80**, 024610 (2009).
[2] R. K. Gupta et al., J. Phys. G: Nucl. Part. Phys. **31**, 631, (2005);A. Kaur, G. Kaur and M. K. Sharma, Nucl. Phys. A **941**(2015) 152-166.
[3] P. A. Seeger, Nucl. Phys. 25, 1 (1961).
[4] G. L. Zhang et al. Chin. Phys. Lett. Vol. **25** No. 4 1247 (2008).