Empirical preformation probability for the decay of ^{226}Ra.

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Introduction

Radioactive heavy nuclei reaches stable region by emitting clusters, apart from emitting α particle, which are heavier than α particle and lighter than the lightest fission fragment, a phenomenon named cluster radioactivity. Cluster decay is studied theoretically by different models based either on Gamow's theory, called as fission models or on shell model. Preformed cluster model of Malik and Gupta [1], associates a parameter, preformation probability, which varies with the size of the clusters and it is defined as the quantum mechanical preformation probability of finding the fragments A_1 and A_2 (with fixed charges Z_1 and Z_2, respectively) through the dynamical collective coordinate of mass and charge asymmetries of the decay products. This quantity is considered to be 1 for α decay in models based on Gamow's theory.

Poenaru and Greiner [2] interpreted the equivalence between the fission model and preformed cluster model, by stating that the preformation probability in fission models can be considered as the penetrability of the prescission part of the barrier. In this work an empirical relation for the preformation factor is attempted based on the relation connecting the difference between the calculated and experimental half-lives of cluster decays and various physical quantities related to the decay.

According to preformed cluster model the decay constant is defined as

$$\lambda = \nu_0 P_0 P \quad (1)$$

with ν_0 is defined as the assualt frequency, P_0 is the preformation factor and P is the penetrability calculated using the excitation model of Greiner and Scheid [3] as a two step process using,

$$P = P_a W_i P_b \quad (2)$$

where,

$$P_a = \exp\left[-\frac{2}{\hbar}\int_{R_t}^{R_a}\{2\mu[V(R)-Q]\}^{1/2}dR\right] \quad (3)$$

$$P_b = \exp\left[-\frac{2}{\hbar}\int_{R_a}^{R_b}\{2\mu[V(R)-Q]\}^{1/2}dR\right] \quad (4)$$

with W_i=1.

Results and discussions

Half-lives of 15 cluster emitters for the experimentally measured cluster decays are calculated using Eq. (1) by taking P_0=1 and P calculated using Eq. (2). There is a large discrepancy between calculated and experimental half-lives with a standard deviation of 8.653. By taking this quantity as $\log_{10}P_0$, the relation connecting this quantity and various physical quantities characterising the decay are fitted, which has the following form,

$$log_{10}P_0 = \gamma X + \beta, \quad (5)$$

where X is the physical quantity characterising the decay, and γ and β the constants.

We present in Table I the quantity X with values of the constants γ and β along with the

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TABLE I: Values of γ and β for different quantities for the equation (5) with the standard deviation calculated between the calculated half-lives for the use of the corresponding $log_{10}P_0$ values and the experimental values.

X	γ	β	SD
Q	-0.1549	0.2709	0.643
Q A_2	-0.0038	-3.1065	0.696
$Q^{1/2}A_2$	-0.0412	-1.3636	0.576
$Q^{3/2}A_2$	-0.0004	-4.06	0.983
$Q\eta$	-0.2312	1.8	0.721
$Q^{1/2}\ \eta$	-4.0995	15.573	0.96
$Q^{3/2}\ \eta$	-0.0193	-1.6929	0.675
Q η A_2	-0.0054	-2.6256	0.63
Q^2	-0.0013	-3.6208	0.815
$\eta\eta_Z$ Q^2	-0.0026	-2.7857	0.709
Q η A_2	-0.0054	-2.6256	0.63
$Q^{1/2}$	-2.257	8.3162	0.711
$Q^{3/2}$	-0.0135	-2.3461	0.683

standard deviation between the newly calculated half-lives using the $\log_{10}P_0$ values corresponding to different fittings and the experimental values of cluster decay. We have applied the relation due to X=Q and the effect of A_2 and η to the complete binary decay of ^{226}Ra. Figure 1 presents the preformation factors calculated using the values of γ and β corresponding to X=Q and the values are compared with our previous results in Ref. [4]. Preformation probability denoted as $P_0(\mu)$ (solid line) is calculated using the idea of Poenaru *et al* [2] and the calculations using the preformed cluster model is denoted by $P_0(PCM)$ (dotted line). Empirical P_0 due to X=Q, compares well with the calculations due to penetrability of the overlapping region denoted as $P_0(\mu)$ in magnitude till the near asymmetric region, but differs completely with $P_0(PCM)$. If the dependence on the mass number of the cluster A_2 is considered, along with Q, the structure is completely washed out and a linear decrease in preformation factor is noted as A_2 increases. Similarly when one considers the role of mass asymmetry (η) with Q, the preformation factor reaches a maximum value for the symmetric region, because

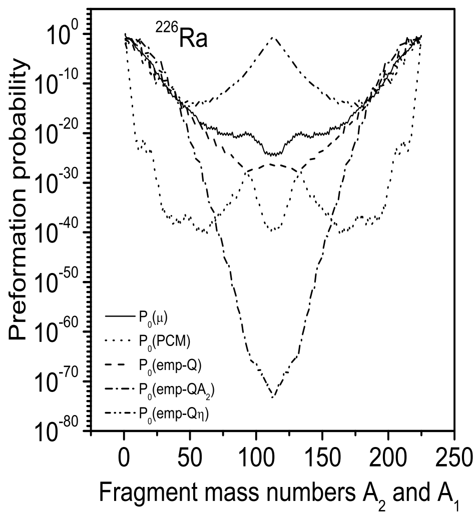

FIG. 1: Preformation values for complete binary spectrum of ^{226}Ra for the use of different models.

the value of η becomes zero, making the γ term zero. For the particle emission of the decay the value of η is $\sim$1, the empirical P_0 value coincides in magnitude as well as structure with $P_0(\mu)$ values.

The results imply that the structural variation in the complete binary spectrum of an element depends strongly on the Q-value of the decay, rather than on A_2 and η.

References

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