Alpha radioactivity of the A=110 isobars near N=Z line

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Introduction

The α-decay based on the concept of "frequency of escape attempts" is one of the powerful tools to investigate the nuclear structure of the exotic nuclei. According to Gamow [1] theory, the α-particle is assumed as a tiny ball moving inside the nucleus, following multiple reflections form the internal walls and finally tunnelling through the potential barrier. About four decades later, on the basis of Quantum mechanical fragmentation theory (QMFT) [2], it was suggested that the preformation probability of decaying fragments plays equally important role, which is estimated using collective clusterization approach. The basis of present study is preformed cluster model (PCM) which depends on both the penetration probability and preformation probability of the decaying fragments. PCM [3] is applied in the present work to explore the α-emission of A=110 isobars of Te, I and Xe nuclei. It will be of interest to analyze the relative role of preformation and penetration factors and accordingly explore the relative stability of these nuclear isobars against α-emission.

Methodology

The preformed cluster model (PCM) [3] uses the collective coordinates of mass and charge asymmetries ($\eta = \frac{A_1-A_2}{A_1+A_2}$ and $\eta_Z = \frac{Z_1-Z_2}{Z_1+Z_2}$), the relative separation R, and the multipole deformations $\beta_{\lambda i}$ and orientations θ_i (i=1,2) of daughter and cluster nuclei which allows to define the decay half-life $T_{1/2}$,

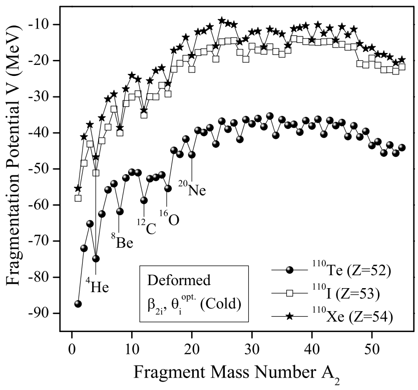

FIG. 1: (a) The fragmentation potentials for the decay of ^{110}Te, ^{110}I and ^{110}Xe parent nuclei plotted for β_2-cold oriented choice at best fitted neck values.

or the decay constant λ as,

$$\lambda = \nu_0 P_0 P, \qquad T_{1/2} = \frac{\ln 2}{\lambda} \qquad (1)$$

Here, ν_0 is the assault frequency, P_0 corresponds to cluster preformation probability and P is the barrier penetrability calculated within WKB approximation. The structure information of the decaying nucleus contained in P_0 is estimated by solving stationary Schrodinger equation in η-coordinate by using the fragmentation potential defined as:

$$V_R(\eta) \;=\; -\sum_{i=1}^{2}[B(A_i, Z_i)] + V_C + V_P \quad (2)$$

where V_C and V_P are, respectively, the Coulomb and nuclear proximity potentials for deformed and oriented nuclei.

Calculations and Results

First of all, we have plotted the fragmentation potential V(η) of the isobars of A=110

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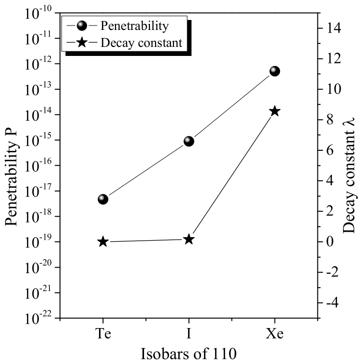

FIG. 2: The penetration probability P (left Y-axis) and decay constant λ (right Y-axis) calculated within the framework of PCM for A=110 isobars.

i.e. ^{110}Te, ^{110}I and ^{110}Xe, illustrated in Fig. 1. The fragmentation potential is calculated by including the quadrupole deformations (β_{2i}) and the cold optimum orientations ($\theta_i^{opt.}$) of the fragments. The figure don't depict significant change in the structure of fragmentation potential with increase in the charge number of the chosen parent nuclei. A clear preference for A_2=4n α-emission can be seen for all the nuclei, particularly for clusters upto $A_2 \sim 40$. The minimas are also visible at ^{8}Be, ^{12}C, ^{16}O, ^{20}Ne but due to lower fragmentation potential of α-particle, the α-emission forms the most favored decay channel. This fragmentation potential serves as an input in the estimation of preformation factor P_0.

Knowing that in PCM, the $T_{1/2}$ is calculated under the combined effect of P_0 and P which means that the penetrability P plays an equally important role in the α- emission process. In view of this, the penetration probabilities and the decay constants of ^{110}Te, ^{110}I and ^{110}Xe nuclei are calculated and plotted in Fig. 2. The penetration probability increases with increase in Z-number of the nuclei and it is found to be lowest for the ^{110}Te nuclear system. The decay constant plotted in same panel shows that it follows a similar trend as that for penetration probability. In a similar way, the dependance of the neck-length parameter on the preformation probability can also be seen from Table I. Including all these

TABLE I: PCM calculated half lives for ^{110}Te, ^{110}I and ^{110}Xe nuclei, compared with experimental data and the corresponding neck values ΔR for α-emission are presented for the parent nuclei.

Parent	Daughter	ΔR	$log_{10}P_0$	$log_{10}T_{1/2}(sec)$	
Nucleus	Nucleus	(fm)		PCM	Expt.[4]
^{110}Te	^{106}Sn	0.27	-9.53	5.297	6.568
^{110}I	^{106}Sb	1.87	0.62	-7.13	0.621
^{110}Xe	^{106}Te	1.1	-1.09	-8.20	-1.044

factors, the PCM calculated α-half lives are presented in Table I and compared with the respective experimental data [4]. It is noticed that the reported α-half lives for the three systems are nicely addressed within the framework of PCM. Table I and Fig. 2 clearly show that the magnitude of preformation and penetration probability for ^{110}Te is minimum among the chosen isobars. As a result of this, $\log_{10}T_{1/2}$ value for the α-emission of ^{110}Te is largest possibly because of the magicity effect in its daughter nucleus. Although, P_0 of α-particle for the case of ^{110}I is highest in comparison to other isobars, but its half-life lies in between ^{110}Te and ^{110}Xe which seems to be largely influenced by the penetrability factor. The above analysis in terms of the fragmentation potential, preformation and penetration probabilities gives an overview of the α-emission from chosen A=110 isobars. It would be of further interest to investigate the decay patterns of different isotopes of Te, I and Xe nuclei and explore the relevance of isobaric and isotopic effects in terms of fragmentation behavior.

References

[1] G. Z. Gamow, Phys. **51**, 204 (1928).
[2] R. K. Gupta, S. Gulati, S. S. Malik and R. Sultana, J. Phys. G **13**, L27 (1987).
[3] S. S. Malik and R. K. Gupta, Phys. Rev. C **39**, 1992 (1989).
[4] J. K. Tuli, Nuclear Wallet Cards (2011), http://www.nndc.bnl.gov/wallet/.