The alpha decay rates of heavy hypernuclei

Kaushal Thakkar[1,3],* Ajay Majethiya[2], and P. C. Vinodkumar[3]
[1] Department of Applied Physics, S. V. National Institute of Technology, Surat-395007, INDIA
[2] V. S. Patel Arts and Science College, Bilimora-396321, INDIA and
[3] Department of Physics, Sardar Patel University, Vallabh Vidyanagar-388120, INDIA

Introduction

Hypernuclear physics is of great interest because it stands at the intersection of nuclear physics, particle physics as well as astro physics. Hypernuclear physics has recently received lot of attention as large number of hypernuclei are produced and studied experimentally. Many future experimental facilities are also planned to study this field of strange matter. For example, the Hyperball collaboration developed an array of germanium detectors with fast electronics for hypernuclear spectroscopy. Details on the progress and scope of this field are available in recent review articles [1, 2]. Here, we make an attempt to identify and study the α decay tunneling probability and half life time of energetically allowed Λ - hypernuclei.

Theory of α decay

Standard α decay theory based on the WKB method is being employed to compute the α tunneling probability. The experimentally known Λ separation energy (S_Λ) [3] and the known binding energies of ordinary nuclei [4] are being used to calculate the Q value for the α decay of the hypernuclei. The hypernucleus is considered as a core of normal nucleus plus the hyperon. For example, the BE of ${}^{89}_{\Lambda}Y$ is calculated as BE(${}^{89}_{\Lambda}Y$) = BE(${}^{88}_{39}Y$)+ S_Λ(${}^{89}_{\Lambda}Y$). There exist experimental hyperon separation energy of many hypernuclei [5, 6]. Wherever the experimental Λ-separation energy is not available, one can use the binding energy formula given by C. Samanta *et al.* [7]. How ever this formula provides binding energies of hyper nuclei with lesser accuracy. Hence for the present study we use an experimentally fitted formula for the lambda separation energy, $S_\Lambda = 19.27 \times e^{0.0015A}$ for the mass number, $A \geq 56$.

The decay constant λ for alpha particle emits from hypernuclei can be written as

$$\lambda = \nu \ T \ P_0 \tag{1}$$

where, ν is the frequency of collision, T is the transmission coefficient and P_0 is the cluster preformation probability. The frequency of collision can be given by

$$\nu = \frac{v}{2b} = \frac{\sqrt{\frac{2E_\alpha}{m_\alpha}}}{2b} \tag{2}$$

Here, E_α is the energy of alpha particle, m_α is the mass of alpha particle and b is the width of the nuclear potential. The effective radius of a non spherical nuclei, R = $1.28A^{\frac{1}{3}} - 0.76 + 0.8A^{-\frac{1}{3}}$ is provided by [8]. The transmission coefficient for alpha particle is given by

$$T = e^{-\frac{2}{\hbar}\int_b^{r_c}[2m_\alpha V(r) - E_\alpha]^{\frac{1}{2}}dr} \tag{3}$$

and

$$\tau_{\frac{1}{2}} = \frac{ln2}{\nu \ T \ P_0} \tag{4}$$

where $V(r) = \frac{2Z_d e^2}{4\pi\varepsilon_0 r}$ and Z_d is the atomic number of the daughter (hyper) nucleus.

Result and Conclusion

The α decay of hypernuclei in the region $A > 100$ are studied within the α decay theory using the WKB approach. The results

*Electronic address: kkt_loc@ashd.svnit.ac.in

TABLE I: The Q value, Coulomb barrier (E_c), tunneling probability (T) and half life time($T_{\frac{1}{2}}$) of α decay in hypernuclei.

Reaction	Q MeV	E_c MeV	T	$T_{1/2}$ S	$\frac{T_{1/2}(\Lambda)}{T_{1/2}(\Lambda=0)}$
${}^{112}_{\Lambda}Te \rightarrow {}^{4}_{2}He + {}^{108}_{\Lambda}Sn$	2.51	22.04	1.69×10^{-32}	1.23×10^{12}	0.006373
${}^{112}_{\Lambda}I \rightarrow {}^{4}_{2}He + {}^{108}_{\Lambda}Sb$	3.15	22.48	1.58×10^{-27}	1.17×10^{7}	0.040194
${}^{112}_{\Lambda}Xe \rightarrow {}^{4}_{2}He + {}^{108}_{\Lambda}Te$	3.65	22.92	8.93×10^{-25}	1.9×10^{4}	0.005563
${}^{238}_{\Lambda}U \rightarrow {}^{4}_{2}He + {}^{234}_{\Lambda}Th$	4.07	31.11	3.28×10^{-43}	6.39×10^{22}	59.52
${}^{223}_{\Lambda}Ra \rightarrow {}^{4}_{2}He + {}^{219}_{\Lambda}Rn$	3.52	30.35	2.29×10^{-46}	9.62×10^{25}	9.67×10^{17}

are listed in Table [I]. Though most of the known Λ-hypernuclei are non-α emitters, the ordinary α emitters in the presence of hyperon (Λ) within the parent or daughter nuclei are found to have considerable effect on their life times. We also find that the hypernuclei are unstable against the hyper-α decay. However, the Λ-binding energy of ${}^{4}_{\Lambda}He$ is much smaller than those with heavy hypernuclei, that reduces the formation of ${}^{4}_{\Lambda}He$ cluster within the heavy hypernuclei. However, there exists possibilities of cluster decays of many of these hypernuclei.

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