Two proton radioactivity in ^{45}Fe and ^{48}Ni

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Introduction

Drip lines are the boundary lines towards neutron and proton axis on the nuclear chart which encloses the stable nuclei. Proton drip line is the boundary line towards the proton axis, which is locus of points with zero separation energy. Nuclear species near the drip lines enter into the stability region by emitting either β^+ or positron or by emitting a proton. An exotic phenomenon of emission of two protons from a nucleus occurs when single proton emission is energetically forbidden. It occurs in a very few nuclei. Two proton radioactivity can be studied in different approaches like simultaneous emission as a three body decay, two body formalism, R-matrix approach and techniques based on the Feshbach reaction theory and continuum shell model [1].

Garrido *et al* [2] employed Coulomb and centrifugal barriers, to study the decay of low lying continuum states into three particle final states. They have chosen hyperradius as the adiabatic coordinate with decay mechanisms as either direct decay or sequential decay. According to them, using WKB method, tunnelling transmission in terms of hyperradius ρ is given as

$$P = \exp\left(-\frac{2}{\hbar}\int_{\rho_0}^{\rho_b}\{2\mu[V(\rho)-Q]\}^{1/2}d\rho\right) \quad (1)$$

where Q is the total energy and V(ρ_0)=V(ρ_b)=Q. The generalised effective radial coordinate expressed as function of hyperradius is given by

$$\rho^2 \equiv \frac{1}{mM}\sum_{i<k} m_i m_k r_i^2 \quad (2)$$

For three body decay, the positive scaling constant s_{ik} is related to hyperradius and the radial coordinate r_i by the expression

$$\frac{r_i^2}{\rho^2} \equiv s_i^2 \quad (3)$$

with

$$s_{ik}^2 = \frac{mM}{\sum_{i<k} m_i m_k} \quad (4)$$

where m is an arbitrary normalization mass, M=$\sum m_i$ and (i,j,k) is permutation of (1,2,3). $s_{12} = s_{23} = s_{13}$ means simultaneous increase of all s_{ik} into direct three body decay. Using generic function,

$$S = \frac{\pi x_t}{2} \quad (5)$$

for the use Coulomb potential for direct decay, the WKB transition probability is reduced to

$$P = \exp\left\{-\pi\left(\sum_{i<k} Z_i Z_k e^2\right)\sqrt{\frac{2\sum_{i<k} m_i m_k}{\hbar^2 QM}}\right\} \quad (6)$$

and half-life is given as

$$T_{1/2} = \frac{\ln 2}{\nu P} \quad (7)$$

Results and discussion

In the present work two proton radioactivity in ^{45}Fe and ^{48}Ni are studied by using the three

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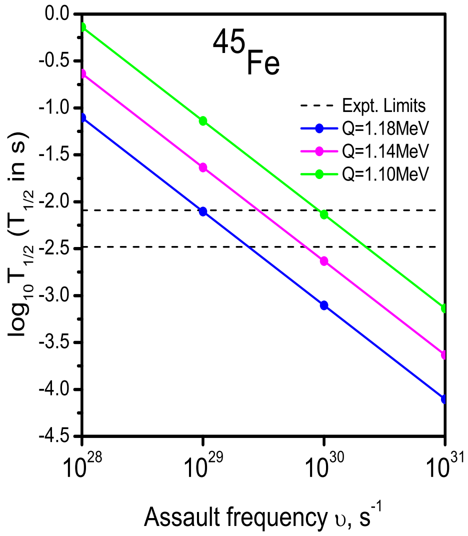

FIG. 1: Experimental and calculated half-lives of ^{45}Fe with Q values varied within the limits.

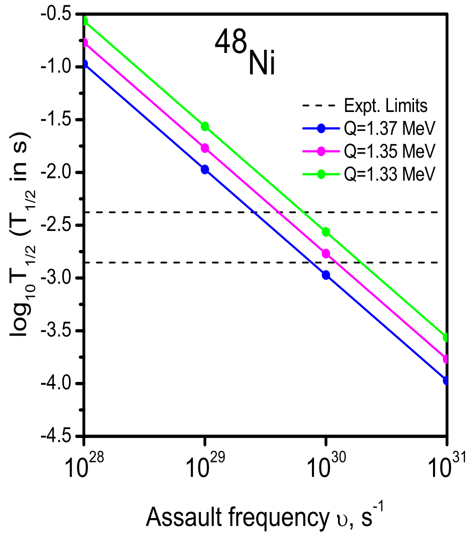

FIG. 2: Experimental and calculated half-lives of ^{48}Ni with Q values varied within the limits .

body analogy. In the this analogy of Garrido *et al* [2], two approaches are used. One is sequential and other is direct decay, for the use two potentials Coulomb and angular momentum potentials. We have used only Coulomb potential for the present work. For the use of Coulomb potential, using the generic function, the WKB transition probability is calculated using Eq. (6). Half-lives are calculated for Q values varied in the given limits using Eq. (7), where ν is assault frequency. Experimental decay energy for ^{45}Fe is 1.14 ± 0.04 MeV and half-life is $4.7^{+3.4}_{-1.4}$ ms [3]. For ^{48}Ni, the decay energy is 1.35 ± 0.02 MeV and the half-life is $2.1^{+2.1}_{-0.7}$ ms [4]. We have used the assault frequency in Eq. (7) as fitting parameter in the expression for half-life. It is varied within the limits 10^{28} s^{-1} to 10^{31} s^{-1}. For ^{45}Fe, calculated logarithmic half-life and experimental values are shown in Fig.1, as a function of assault frequency (ν) for the three limiting Q values. Calculated half-life better fits with the upper limit of experimental value, when the assault frequency is 10^{29} s^{-1} and 10^{30} s^{-1} for Q values 1.18 MeV and 1.10 MeV respectively.

In the case of ^{48}Ni, the half-lives are compared in Fig. 2. In this case, the calculated logarithmic half-life falls within the experimental limits when the assault frequency is 10^{30} s^{-1} for the Q values 1.35 MeV and 1.33 MeV. For Q=1.37 MeV, with assault frequency 10^{30} s^{-1}, the calculated logarithmic half-life deviates from experimental value by less than one order of magnitude. When we compare the fitted assault frequency, with that of either alpha decay and single proton decay, a difference of 8 or 9 order of magnitude is found.

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