Studies on the two-proton radio activity using the simplified form of effective liquid drop model

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Introduction

Theoreticians are made great effort to predict two proton radioactivity. The two proton radioactivity was discovered experimentally after the growth of radioactive beam facilities and detection technologies. At present many theoretical models have been proposed by the theoreticians for predictions of the two proton decay studies.

Effective liquid drop model (ELDM) [1] is one of the models for predicting two proton radioactivity. In the present work we have made an attempt to modify the effective liquid drop model in to a simplified form by changing the Coulomb potential in the driving potential model of ELDM. Using this model, we have computed the two proton decay half-lives of ^{16}Ne, ^{19}Mg, ^{45}Fe and ^{48}Ni isotopes. We have computed the separation energy for one proton and two proton decay and also analysed the driving potential for these isotopes with different angular momentum (l=0,1,2,3).

The model

Separation energy for one proton, two proton decay can be calculated as

$$S(p) = -\Delta M(A,Z) + \Delta M(A-1, Z-1) + \Delta MH \quad (1)$$

$$S(2p) = -\Delta M(A,Z) + \Delta M(A-2, Z-2) + 2\Delta MH \quad (2)$$

Q value of the two proton decay is

$$Q = \Delta M(A,Z) - (\Delta M(A-2,Z-2) + 2\Delta MH) + k(Zp^{\varepsilon} - ZD^{\varepsilon}) \quad (3)$$

ΔM (A, Z), ΔMH, ΔM (A-1, Z-1), ΔM(A-2, Z-2) are the mass excess of the parent nuclei, proton, daughter nuclei produced during one proton, two proton decay respectively. The Q values are computed using the table of Wang et al [2]. k=13.6eV, ε=2.408 for Z >60 and ε=2.517 for Z ≤60. R_D, R_2p are the radius of daughter and 2p emitter respectively. ζ is distance between their geometrical centers. The variable ξ represents the distance between the center of the daughter nucleus and the circular sharp neck of radius 'a' is given in[1].

If Z_P, Z_{2P} and Z_D are the atomic number of parent nucleus, daughter, and emitted respectively, the total potential energy constructed as

$$V(\zeta) = \frac{KZ_P Z_{2P} e^2}{\zeta} + Vs(\zeta) + \frac{\hbar^2 l(l+1)}{2\mu\zeta^2} \quad (4)$$

The total potential energy is sum of coulomb potential, surface potential and centrifugal potential energy .μ is the reduced mass of the nuclear system.

$$Vs(\zeta) = \sigma_{eff}(S_{2P} + S_P) \quad (5)$$

Where S_D and S_{2p} are the surface are of daughter and emitter nuclei. The barrier penetrability factor G is given as

$$G = \exp\left\{ \frac{-2}{\hbar} \int_{\zeta_0}^{\zeta_c} \sqrt{2\mu[V(\zeta) - Q]} d\zeta \right\} \quad (6)$$

Inner turning point $\zeta_0 = R_p - R_{2p}$ outer turning point

$$\zeta_c = \frac{Z_P Z_{2P} e^2}{2Q} + \sqrt{\left(\frac{Z_P Z_{2P} e^2}{2Q}\right)^2 + \frac{l(l+1)\hbar^2}{2\mu Q}} \quad (7)$$

Half-lives is calculated as $\tau_c = \ln 2/\lambda$ where the decay rate is equal to $\lambda = \lambda_0 G$. λ_0 in the range of 10^{19}-10^{20} we taken $\lambda_0 = 4.96\times10^{19}$

Result and Discussions

The one proton and two proton decay separation energy is computed for the ^{16}Ne, ^{19}Mg, ^{45}Fe and ^{48}Ni isotopes is given in table 1. It is obvious from the table that the separation energy of two proton decay is less than one proton decay. Separation energy is the minimum energy required to remove a proton from nucleus. This shows that these nuclei will requires less energy to emit two protons from nuclei comparing to one proton.

Parent Nucleus	S(1p) (MeV)	S(2p) (MeV)
^{16}Ne	-0.131	-1.401
^{19}Mg	0.499	-0.752
^{45}Fe	0.559	-1.152
^{48}Ni	0.869	-1.302

Table 1: 1p and 2p separation energy of various nuclei

we have also computed the driving potential of ^{16}Ne, ^{19}Mg, ^{45}Fe and ^{48}Ni isotopes with all the possible combinations by varying the angular momentum(l=0,1,2,3). Figure 1 represents the plot connecting the driving potential versus atomic number of fragments of ^{16}Ne isotopes.

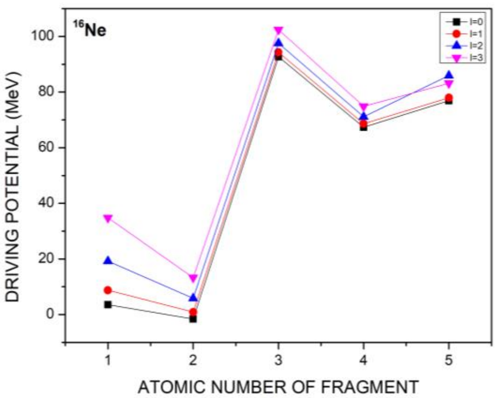

Fig. 1 The driving potential for ^{16}Ne nucleus as a function of the emitted fragment for l=0.1,2,3

It is obvious from the figure that the emitted fragment two proton have minimum driving potential. Angular momentum l=0 shows the minimum driving potential. The driving potential shows the height of barrier potential. The lower driving potential indicates that the height of the barrier potential is low, thus makes easy to barrier tunneling process. All other fragment 1p, ^{3}He,^{4}He,^{5}Li have higher value comparing to 2p, this show that 2p have high chance of emission from the nucleus of ^{16}Ne. similar results is obtained in the case of ^{19}Mg, ^{45}Fe, ^{48}Ni isotopes that the two proton have minimum driving potential that means the two proton decay is probable decay for emission from these isotopes.

Figure 2 represents the plot connecting the computed half lives of two proton decay versus atomic number of parent nuclei using the present model. The computed half lives is compared with the predictions of ELDM[1], GLDM[3], and the empirical formula predictions of I. Sreeja et al [4]. It is found the plot that predicted half life time values are in close agreement with the experimental values. We would like to mention that the present half-lives are in agreement with the predictions of GLDM and the empirical formula predictions. But there is a slight deviation in the predictions of Effective liquid drop model. We presume that this is very simplified form to compute the decay half-lives.

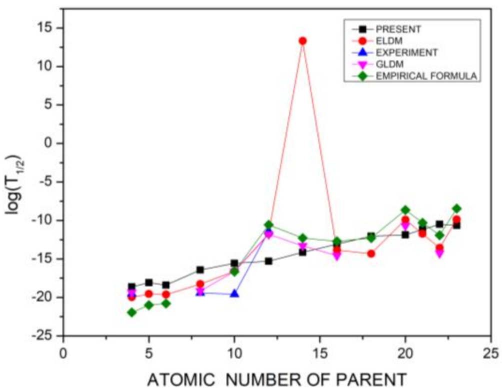

Fig. 2 Plot of $\log_{10}T_{1/2}$ versus atomic number of parent nucleus

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