Prediction of alpha decay energy and alpha decay half life of unknown alpha decaying systems

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Introduction

In this work, we calculate the energy and half life of an alpha decaying system within the framework of three-dimensional potential scattering using an analytically solvable potential developed by Sahu [1]. This potential simulates the nuclear Woods-Saxon part in the inner region and Coulomb part in the outer region obtained by using the calculations based on mean field theoretic methods [2]. The form of the potential along with the exact solution of the Schrödinger equation is given in ref. [1]. Potential presented in ref. [1] has five parameters $r_0, a, B_0, b_1 = \sqrt{B_1} A_t^{-1/3}$ and λ_1 for the estimate of resonance energy and half life $t_{1/2}$. In the calculations only one parameter λ_1 has been varied within the range $1 < \lambda_1 < 2$, remaining four parameters are fixed at $r_0 = 0.97\,fm$, $b_1 = 0.82$, $a = 1.6\,fm$ and $B_0 = -78.75 MeV$.

Global formula

For the predictions we have developed a global formula to fix the value of parameter λ_1, which has been calculated by using the formula for each nuclei of the isotopic chain. The formula has been developed in terms of λ_1 as a function of neutron number N_t of the target nuclei. To develop a global formula, we have plotted a graph between neutron numbers of the target nuclei and the value of λ_1 obtained by fitting the experimental results of the decay energy for the Pb isotopes with Z=82 [1]. Plot is shown in fig.1 Formula is given as

$$\lambda_1 = \begin{cases} \lambda_0 (N_{t0}/N_t) & \text{if} \quad N_t < N_{t1} \\ \lambda_0 (N_{t0}/N_{t1}) \times (N_{t1}/N_t)^2 & \text{if} \quad N_t > N_{t1} \end{cases} \qquad (1)$$

where λ_0 is starting value for a given isotopic chain. N_{t0} is initial value of neutron number, N_{t1} is central value of neutron number. Thus this formula gives the value of λ_1 for a given N of the isotopes.

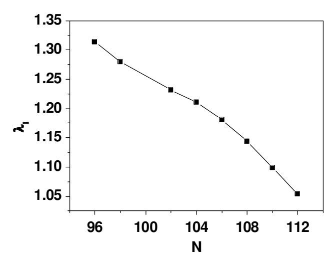

Fig 1 the dots indicate the values of λ_1 which explain the respective experimental Q values. The solid curve represents the global formula given by equation (1) for λ_1 as a function of neutron number N, with $N_{t0} = 96$, $N_{t1} = 105$ and $\lambda_0 = 1.313$.

Result and discussion

To see the reliability of global formula we have applied (1) to the isotopic chain of Z=74. Results are shown in table 1 and table 2. In table 1 and table 2 we have presented the calculated Q-value and half life for the nuclei of isotopic chain of alpha emitter Z=74. First column of table 1 shows the mass number of target nuclei and the second column shows the values of λ_1

estimated by using the global formula (1). Corresponding Q-value calculated by using RPD method is given in column 3. In column 4, experimental Q-value has been given for comparison. The results in the table 1 show that Q-values calculated in the present work are very close to the experimental Q-values. Further, the table contains the predicted results of our calculation for the decaying isotopes for which experimental data are not available. It can be confirmed by measurements. In table 2, column 2 and column 3 show calculated and experimental half life, respectively.

Table 1. Prediction of alpha decay half life and Q values for the isotopic chain of Z=74. Potential parameters are fixed at $r_0 = 0.97 fm$, $b_1 = 0.82$ $a = 1.6 fm$ and $B_0 = -78.75 MeV$. Parameters of the global formula are $\lambda_0 = 1.245$, $N_{t0} = 82$, and $N_{t1} = 87$.

A_t	λ_1	Q^{cal}	$Q^{(exp)}$
154	1.24520	6.61	6.61
155	1.230197	6.41	-
156	1.215552	6.22	-
157	1.201251	6.03	-
158	1.187283	5.84	5.67
159	1.173636	5.65	5.52
160	1.147114	5.37	5.28
161	1.12148	5.10	-
162	1.09669	4.82	4.86
163	1.072727	4.54	-
164	1.049534	4.27	-

Table 2: Half life calculated for the same isotopic chain as in table 1 by using the value of λ_1 and Q^{cal} given in table 1.

A_t	$t_{1/2}^{cal}$	$t_{1/2}^{(exp.)}$
154	1.7×10^{-4}	9.0×10^{-4}
155	8.0130×10^{-4}	-
156	3.8466×10^{-3}	1.0×10^{-1}
157	1.9560×10^{-2}	-
158	1.0915×10^{-1}	3.00
159	6.444×10^{-1}	6.76
160	1.103×10^{1}	2.5×10^{2}
161	2.327×10^{2}	-
162	6.2551×10^{3}	4.7×10^{2}
163	2.446×10^{5}	-
164	1.10×10^{7}	1.6×10^{6}

Half lives have been calculated by using wave function method [1]. It is observed that the calculated results of half lives are close to the corresponding experimental results for most of the isotopes. More importantly, the explanation of the measured results of long lives in the cases with large mass numbers is remarkable in this analysis. In some cases the fitting of the data is not good. It can be improved further by using slightly different values for the potential parameters b_1 and λ_1.

References

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