Nuclear radius parameters of odd-A and even-A alpha emitters

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Introduction

The calculated alpha Hindrance Factor (HF) is a crucial parameter for deciding J^π and nucleonic configuration assignments to the states involved in favored alpha transitions observed in even-even, odd-odd and odd-A nuclides. Recently, we calculated nuclear radius parameters (r_0) for 182 even-even alpha emitters [1] throughout periodic table using Preston's spin-independent equations of alpha-decay [2]. In present study, we deduced the values of r_0 parameters for odd-odd and odd-A alpha emitters by using neighboring even-even radii. Additionally, the behavior of r_0 parameters with parent neutron number is also presented for odd-odd and odd-A nuclides.

Methodology

In our recent study [1], we used the spin–independent part of Preston's equations [2] of alpha-decay to calculate nuclear radius parameter (r_0) for 182 even–even alpha emitters by equating the calculated transition probability for an alpha transition from ground state of the α-parent to the ground state of daughter ($0^+ \rightarrow 0^+$ α-transition) to the experimental transition rate [3]. The input parameters required for these calculations are: energy available for α-decay (Q_α), half-life ($T_{1/2}$) of the parent nuclide, alpha–decay branching ratio (%α), and alpha intensity (I_α) for ground-state to ground-state α-transition. We evaluated these quantities and hence calculated r_0 parameters for even-even nuclides. In these calculation we pin-pointed that, the calculated r_0 parameters for above said even-even nuclides shows a smooth regular behavior with increasing neutron numbers between closed shells. Based on the assumption that, the r_0 parameters for odd-odd and odd-A nuclides lie midway between those of adjacent even-even nuclides, we deduced the value of r_0 parameters of odd-A nuclides by using an interpolation procedure equivalent to unweighted average of r_0 parameters of two nearest even-even neighbors. Similarly for odd-odd nuclei, an average of four nearest even-even neighbors is taken and our RadD subroutine is used for these deductions of radius parameters [4].

Results and Discussion

In present study, we deduced the r_0 parameters for, 82 odd-even, 97 even-odd and 61 odd-odd alpha emitters by averaging r_0 parameters of nearest even-even neighboring nuclides. The systematics of r_0 parameters with parent neutron number for odd-even nuclides obtained in present study is shown in Fig. 1.

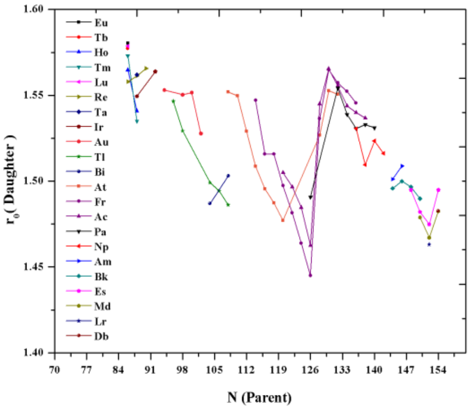

Figure 1: Systematics of r_0 parameters for odd-even nuclides obtained in present study.

From this Figure it is clear that, the r_0 parameters lie on fairly smooth curves with exceptions at major and minor shell closures. In other words, the calculated r_0 parameters for all the nuclides decrease gradually with increasing neutron number between neighboring closed shells, exhibiting a minimum at N=126 (a major shell closure), and increase thereafter, decreasing again toward the next minor shell closure at N=152 which is consistent with recent mapping of shell effects [5].

A similar behaviors of r_0 parameter systematics is observed in even-odd and odd-odd nuclides as shown in Fig. 2 and Fig. 3, respectively.

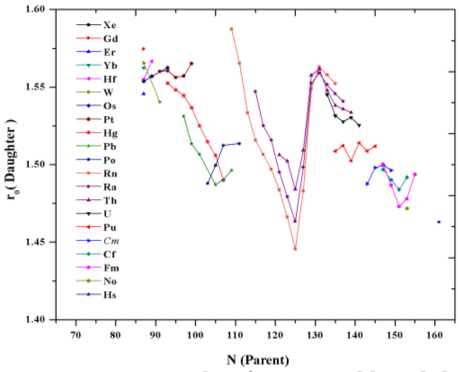

Fig. 2: Same as Fig. 1 but for even-odd nuclides.

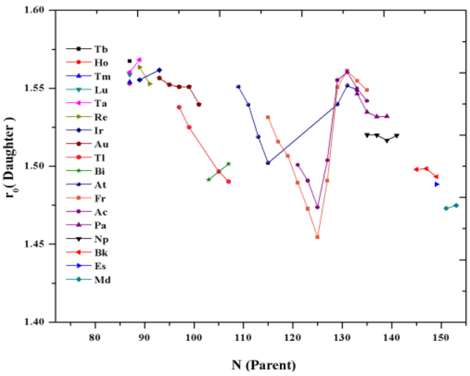

Fig. 3: Same as Fig. 1 but for odd-odd nuclides

The r_0 parameters obtained in present study can be used to calculate HFs of various alpha transitions observed in odd-A and even-A alpha emitters. These calculated HFs further plays a crucial role in deciding spin-parity and nucleonic configurations of the states involved in favored alpha transitions observed in these nuclides.

As discussed above, the experimental quantities required to calculate r_0 parameter of even-even nuclides are: energy available for α-decay (Q_α), half-life ($T_{1/2}$) of the parent nuclide, alpha–decay branching ratio (%α), and alpha intensity (I_α) for ground-state to ground-state α-transition. In the present study, we also pin-pointed some even-even nuclides for which number of values of %α are listed in literature for same ground-state to ground-state α-transition, but experimental information for selection of appropriate alpha branching is not available. In these cases, we used radius parameter systematics to predict best possible value of alpha-branching as discussed below for one particular case namely ^{156}Er→^{152}Dy alpha decay.

For this alpha decay, there are four different experimental measurements of %α and the calculated values of r_0 parameters corresponding to these different values of alpha branching are shown in Table 1. The other evaluated parameters used for this particular nuclide are Q_α = 3481 (25) keV, half-life ($T_{1/2}$) of the parent nuclide as 19.5(10) *min* and alpha intensity (I_α) as 100 [1].

Table 1

%α	r_0 (fm)	Key number*
5.0×10^{-8} (2)	1.541(26)	1995KAZS
1.2×10^{-7}(3)	1.588(30)	1996BYZY
5×10^{-7}(2)	1.665(27)	1992KAZP
1.0×10^{-6}	1.704(27)	2002KAZR

*Nuclear Science References available at www.nndc.bnl.gov

In order to determine branching ratio consistent with r_0 systematics, we compared values of r_0 parameters obtained for all the above said branchings with r_0 parameters of adjacent nuclides namely ^{148}Dy (r_0=1.5661(28)) and ^{150}Dy (r_0=1.550(16)). From present systematics of r_0 parameter in adjacent nuclides ^{148}Dy and ^{150}Dy, we suggest that, the most likely value of %α for ^{152}Dy as 5.0x10^{-8}(2) (1995KAZS) as other values of alpha branching yields drastically higher value of r_0 parameter. Similarly on the basis of radius parameter systematics appeared in other nuclides, we suggested most appropriate values of %α in these nuclides and more experimental measurements are required to confirm present predictions.

Acknowledgement

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