Empirical formula for the most stable isobar against beta decay

M. K. Preethi Rajan[1], R. K. Biju[2], and K. P. Santhosh[1,]*
[1]*School of Pure and Applied Physics, Kannur University, Payyanur Campus, Payyanur-670327, INDIA*
[2]*Department of Physics, Pazhassi Raja N S S College, Mattanur- 670702, INDIA*
** email: drkpsanthosh@gmail.com*

Introduction

Many of the nuclei produced in the lab are radioactive. The degree of instability grows as the distance of a given nuclide increases from the stable nuclide with the same mass number [1]. An unstable nuclide attains stability through different decay mechanisms such as alpha decay, beta decay, gamma decay, cluster radioactivity etc. In the present work we have developed a formula for finding the most stable isobar for a given mass number against beta decay. We have also studied the mass parabola for different isobars with mass number ranging from 200-223. It was found that the lowest point in the parabola, which is the Z value of most stable isobar against β decay, matches well with our formula predictions.

Stability of nuclei against beta decay

One of the main applications of Bethe-Weizsacker semi empirical mass formula is the prediction of the most stable isobar of a given A against beta decay. The Z value of such isobar is given by minimizing the atomic mass including the mass of electron from the semi empirical mass formula. This gives

$$Z_A = A\frac{2a_A + (m_n - m_p - m_e)c^2/2}{4a_A + a_C A^{2/3}} \qquad (1)$$

Where $a_A = 23MeV$ and $a_C = 0.72MeV$ are the coefficient of asymmetry term and Coulomb term in the semi empirical mass formula and m_n, m_p, m_e are mass of neutron, proton and electron respectively.

We have computed the Z_A value for different isobars in the heavy region with mass number varies from 200 to 250. Figure 1 represents the plot of mass number versus the atomic number of most stable isotopes (Z_A) against beta decay. It is obvious from the plot that Z_A values show a linear relationship with the mass number. From the linear dependence of mass number and Z_A value, we have developed an empirical formula for the most stable isobar of a given A against beta decay and is given as,

$$Z_A = aA + b \qquad (2)$$

The parameters are, $a = 0.33796$ and $b = 11.97723$. We have also compared the present formula predictions with those obtained from eqn. 1 and are shown the figure 1. It is found that the present formula predictions are in close agreement with the formula predictions of equation 1. We would like to point out that the present formula is much simpler as compared to other empirical formulae. Hence the present equation is better to identify the stability of the isotopes against beta decay in the heavy region.

Mass parabola

We have also studied the mass parabolas for different nuclides with mass number ranging from 200-223 and are shown in the figure 2 to 4. Mass parabola is a plot of atomic masses versus Z for different nuclei of same mass number. The minimum of the parabola gives the Z value of most stable isobar against beta decay. It is found that there is good match between our formula prediction of Z and minimum of mass parabola for the considered range of mass numbers.

The mass parabolas for the different isobars fall in two categories according to whether A is odd or even. Figure 2 represents the plot for atomic mass versus proton number for the different odd A isotopes in the heavy region with mass number varies from 201-207. It is obvious from the plots that for nuclei with odd A, a single parabola is obtained irrespective of whether the nucleus is odd-even or even-odd. In this case the pairing term in the binding energy does not change from isobar to isobar and the question of stability relies on the balance between the symmetry term which prefers equal numbers of protons and neutrons and the Coulomb term which prefers fewer protons. For such nuclides there is only one stable isobar with some atomic number Z_A. The nuclides falling on either side of this isobar are all unstable. The isobars on the lower Z side have too many neutrons for stability and are β^- active and those on the higher Z side have too many protons and hence undergo β^+ decay.

Figures 3 to 4 represent the plot of atomic mass versus proton number for the different even-even and odd-odd isotopes in the heavy region with mass number varies from 208-222. For nuclei with even A, because of the influence of pairing term in the binding energy, there are two mass parabolas for the same mass number. The parabola for the odd-odd nuclei lies above that of the even-even nuclei. Here all the odd-odd nuclides have larger atomic mass than one of the adjacent even- even nuclides and the most stable isobar falls on the lower parabola. For the nuclide lying at the lowest point in odd-odd parabola both electron emission and positron emission are energetically possible. Thus in some cases there can be two even-even isobars for which Z differs by two units. In all these cases the most stable isobar against beta decay is obtained as the lowest point in the parabola which is in good agreement with our formula predictions. The minima in mass parabolas shows stability of the isobar against beta decay. Hence we would like to propose that it will be a guide to the future experiments in beta decay in the heavy region.

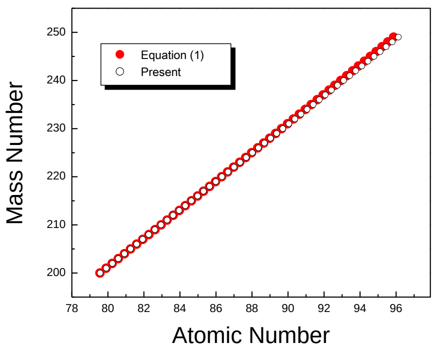

Fig. 1 plot of comparison of Z value of most stable isobar against beta decay obtained from equation 4 and the present formula.

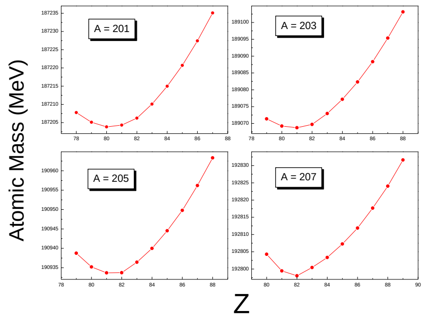

Fig. 2 Mass parabolas for different isobars with mass numbers 201,203,205 and 207

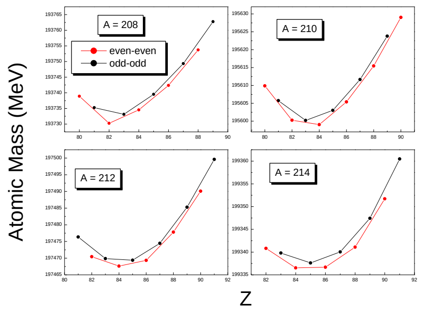

Fig. 3 Mass parabolas for different isobars with mass numbers 208,210,212 and 214

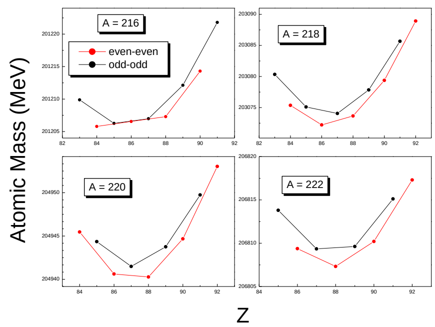

Fig.4 Mass parabolas for different isobars with mass numbers 216,218,220 and 222

References

[1] Jozsef Konya, Noemi M. Nagy, Nuclear and Radiochemistry, 74 (2012)