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# A Theoretical Account on Beta Decay Stability for Isobaric Family

**M. Nageshwari***

Department of Physics, Bharath Institute of Higher Education and Research, Chennai, Tamil Nadu, India; pbp_28@yahoo.co.in

## Abstract

Nucleides with same mass number but with different atomic number are called isobars. Most of the unstable nucleides are β emitters. The stability of β emitting isobars is predicted from mass parabolas. Using semi empirical formula masses are calculated and mass parabolas are drawn for odd A and Even A isobars. All isobars decays into stable isobar by $\beta^+$ emission or $\beta^-$ emission or electron capture. This study gives the theoretical account for the beta decay stability against mass parabolas for isobaric family.

**Keywords:** Beta Decay, Isobar, Mass Parabola, Stability

## 1. Introduction

Atoms are made up of subatomic particles protons, neutrons and electrons. The atom is the smallest particle that possesses the characteristics of a particular element. An atom is believed to consist of a small massive core called the nucleus, surrounded by orbiting electrons. In nuclear physics, beta decay is a type of radioactive decay in which a beta particle is emitted from an atomic nucleus. Beta decay is a process which allows the atom to obtain the optimal ratio of protons and neutrons[2]. Isobars are atoms different chemical elements that have the same number of nucleons. Isobars differ in atomic number but have the same mass number. An example of a series of isobars would be $^{40}S$, $^{40}Cl$, $^{40}Ar$, $^{40}K$, and $^{40}Ca$. The nuclei of these nuclides all contain 40 nucleons; however, they contain varying numbers of protons and neutrons[4]. Beta particles are electrons which carry (-e).In the case of $\beta^-$ decay Z increases by one unit. In the case of $\beta^+$ decay Z decreases by one unit. The theory of electron capture was first discussed by Gian-Carlo Wick in a 1934 paper, and then developed by Hideki Yukawa and others. K-electron capture was first observed in 1937 by Luis Alvarez, in the nuclide $^{48}V$[1].

## 2. Isobaric Family

Atoms having the same mass number but different atomic number are known as isobars. A pair of isobars cannot belong to same chemical element.

## 3. Beta Decay

The portion of the radiation emitted from a radioactive source that was strongly deflected by perpendicular magnetic field was termed as beta radiation. There are three modes of beta radioactivity. Negatron emission, orbital electron capture and positron emission. Negatron emission is much more common than the other decay processes. Beta rays are easily distinguished from α particles by their considerably range in matter. When a radioactive element emits a $\beta^-$ particle, the product has the same mass number as a parent, but its atomic number is greater by one unit. Similarly when a positron is emitted the mass number is still unchanged but the atomic number of the product is now one unit less than that of the parent. When the ratio of neutrons to proton ratio is low, another type of decay known a orbital electron capture process has been found to occur. In this process instead of proton being

*Author for correspondence

converted into a neutron by the nucleus from the first or any other quantum level which combines immediately with a proton to form a neutron. The product of this type would have the same mass number as its parent but its atomic number would be one unit lower as in the case of positron emission[3].

## 4. Weissacker Semi Empirical Formula

A great deal of importance has been attached to the mass and binding energy of the nucleus and a formula which would allow the calculation of nuclear masses would be very useful has been developed and is called the semiempercal formula. It is related to the liquid drop model of the nucleus.

Using semi empirical formula, Weissacker in 1935 showed that it is possible to achieve a quantitative and more basic understanding of binding energies of nuclei. He developed a mass formula which has many practical applications. In particular it is able to predict the stability against beta decay for the members of isobaric family.

$$M(Z,A) = AMn - Z(Mn - Mp) - B$$

$$= AMn - Z(Mn - Mp) - avA + \frac{asA2}{3} +$$

$$ac\frac{Z(Z-1)}{A^{\frac{1}{3}}} + aa\frac{(A-2Z)^2}{A} + ap\ A^{-\frac{3}{4}}$$

## 5. Mass Parabolas

In semi empirical formula, keeping A as constant and vary the Z (atomic number) the masses for different nucleides of isobars have been calculated. The masses decrease with increasing Z and then increases. The isobar, for which the mass is minimum showing maximum stability, is at or near the bottom of the curve. Here mass parabolas for odd A and even A nucleides are drawn.

**Classification of stable nucleides**

| A | Z | N | Number of stable nuclei |
|---|---|---|---|
| Even | Even | Even | 165 |
| Odd | Even | Odd | 55 |
| Odd | Odd | Even | 50 |
| Even | Odd | Odd | 4 |

## 6. Results and Discussion

Beta decay stability against the members for the following odd A nuclei and even A nuclei were considered for isobaric family.

**Odd A**

1. For A=91 with Z=36 to 42

| Atomic number Z | Element |
|---|---|
| 36 | Kr |
| 37 | Rb |
| 38 | Sr |
| 39 | Y |
| 40 | Zr |
| 41 | Nb |
| 42 | Mo |

2. For A=65 with Z=27 to 32

| Atomic number Z | Element |
|---|---|
| 27 | Co |
| 28 | Ni |
| 29 | Cu |
| 30 | Zn |
| 31 | Ga |
| 32 | Ge |

**Even A**

1. For A=64 with Z=27 to 31

| Atomic number Z | Element |
|---|---|
| 27 | Co |
| 28 | Ni |
| 29 | Cu |
| 30 | Zn |
| 31 | Ga |

2. For A=200 with Z=77 to 82

| Atomic number Z | Element |
|---|---|
| 77 | Ir |
| 78 | Pt |
| 79 | Au |
| 80 | Hg |
| 81 | Ti |
| 82 | Pb |

In this project the Weissacker semi empirical formula has been taken. Using this formula, the atomic masses are determined and mass parabolas are drawn. Mass parabolas are drawn for odd A and even A nuclei. The stability graph for $\beta^-$ decay, $\beta^+$ decay, electron capture for the members of the isobaric family to become stable elements is obtained very clearly. The graph itself explains the stability of the isobaric family against beta decay.

**Odd A nuclei:**

The results are different for the members of the isobaric family with odd A and even A nuclei because of the pairing term. In the case of odd A nuclei, the pairing term is zero, so only one parabola is obtained.

**1. A=91**

The isobaric family for A=91 is considered. The parabolic relationship between masses and Z=91 along with the beta decay is shown in the Figure 1 and Table 1. Zr is the most stable isobar having minimum mass. All other isobars whose masses are greater than the stable one lies on the two arms of the curve.

The elements on the left arm of the parabola emits ${}_{40}Zr^{91}$

$${}_{36}Kr^{91} \rightarrow {}_{37}Rb^{91} \rightarrow {}_{38}Sr^{91} \rightarrow {}_{39}Y^{91} \rightarrow {}_{40}Zr^{91} \text{ (stable)}$$

$${}_{42}Mo^{91} \rightarrow {}_{41}Nb^{91} \rightarrow {}_{40}Zr^{91}$$

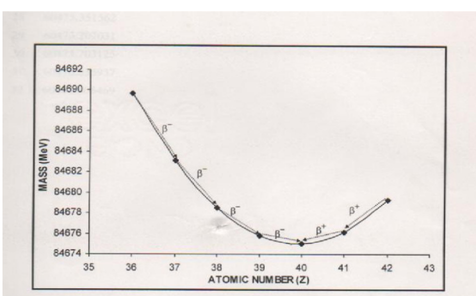


**Figure 1.** A=91.

**Table 1.** For A=91

| Atomic number (Z) | Mass(M) |
|---|---|
| 36 | 84689.72 |
| 37 | 84683.13 |
| 38 | 84678.48 |
| 39 | 84675.76 |
| 40 | 84674.99 |
| 41 | 84676.14 |
| 42 | 84679.25 |

**2. A=65**

The isobaric family for A=65 is considered. Using the above procedure the masses are calculated and mass parabola is drawn. Here copper (Cu) is the most stable isobar (Figure 2 and Table 2).

**Even A nuclei**

The results for even A nuclei are different from odd A nuclei because of the pairing term. In the case of even A isobar, for even-even nuclei, the pairing term is negative and for odd-odd nuclei the pairing term is positive. Hence there are two parabolas. The upper curve is for odd Z-odd N and the lower curve is for even Z and even N.The isobars of even Z –even N fall on the lower parabola and they are more stable.

**1. A=64**

The isobaric family for A=64 is considered. The parabolic relationship for A=64 along with the beta decay is shown in Figure 3 and Table 3. There are two curves. The nucleides ${}_{27}Co^{64}$, ${}_{29}Cu^{64}$, ${}_{31}Ga^{64}$ lies on the upper curve. The nucleides ${}_{28}Ni^{64}$ , ${}_{30}Zn^{64}$ lies on the lower curve. All the isobars decay into stable isobar either by $\beta^-$ emission and $\beta^+$ emission. There are two stable nuclei .The stable isobars are $Ni^{64}$ and $Zn^{64}$

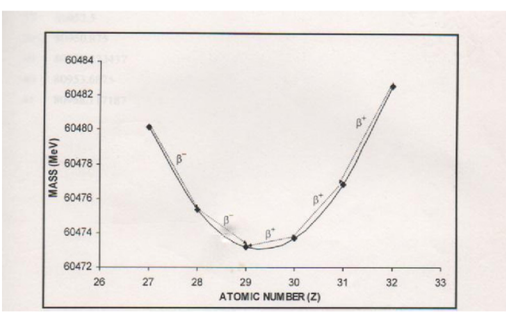


**Figure 2.** A=65.

**Table 2.** For A=65

| Atomic number (Z) | Mass(M) |
|---|---|
| 27 | 60480.12 |
| 28 | 60475.35 |
| 29 | 60473.20 |
| 30 | 60473.70 |
| 31 | 60476.83 |
| 32 | 60482.60 |

**2. For A=200**

The isobaric family for A=200 is considered. The parabolic relationship for A=200 along with the beta decay is shown in Figure 4 and Table 4.There is only one stable isobar in the case of A=200. The stable isobar is mercury

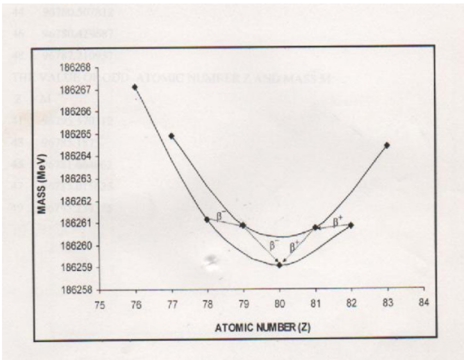


**Figure 3.** A=64.

**Table 3.** For A=64

| Even Z | Mass M | Odd Z | Mass M |
|---|---|---|---|
| 26 | 59552.22 | 27 | 59548.77 |
| 28 | 59542.08 | 29 | 59543.99 |
| 30 | 59542.64 | 31 | 59549.90 |
| 32 | 59533.91 | | |

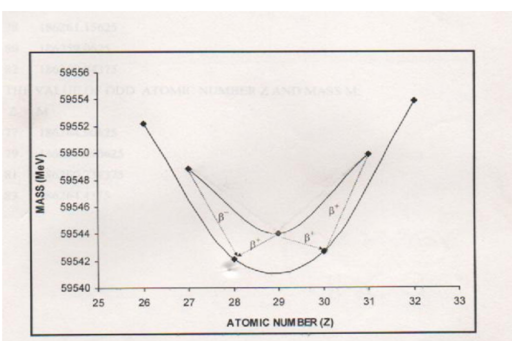


**Figure 4.** A=200.

**Table 4.** For A=200

| Even Z | Mass M | Odd Z | Mass M |
|---|---|---|---|
| 76 | 186267.10 | 77 | 186264.90 |
| 78 | 186261.15 | 79 | 186260.89 |
| 80 | 186259.06 | 81 | 186260.73 |
| 82 | 186260.84 | 83 | 186264.43 |

## 7. Conclusion

The theoretical study for the stability of the isobaric family against beta decay is done. The mass parabolas are drawn for isobaric family. The nuclear stability of the beta emitting isobars is predicted using the mass parabolas. For odd A, there is only one stable nucleus and for even A, there is one, or more than one stable nuclei.

## 8. Acknowledgement

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