VIVEKANANDA COLLEGE
THAKURPUKUR
KOLKATA-700063

NAAC ACCREDITED 'A' GRADE

Topic: Energetic of Beta Decay

Course Title: Elements of Modern Physics

Paper: PHS-A-CC-4-9-TH

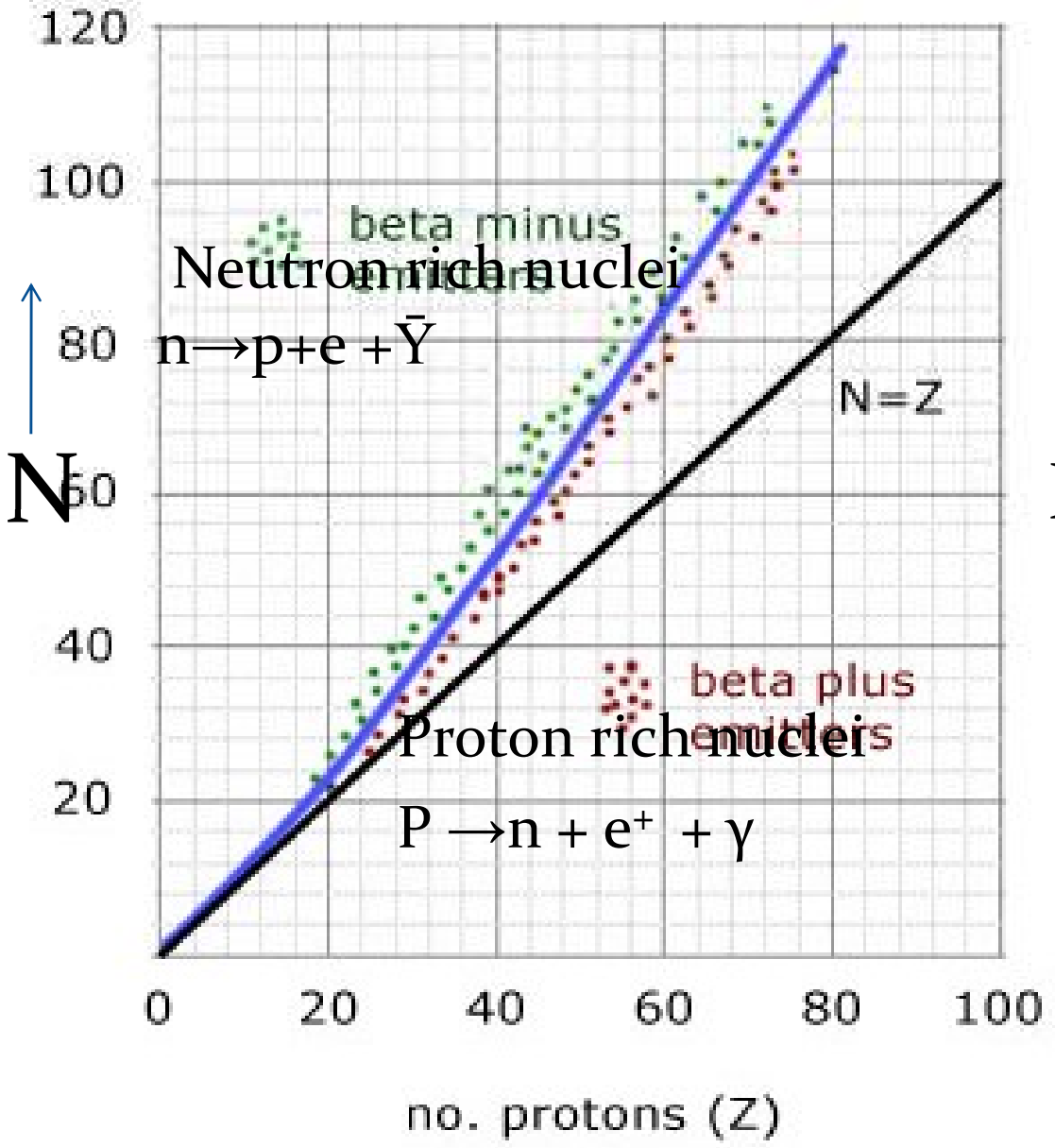
Unit: 4

Semester: 4

Name of the Teacher: Dr. Nirmalya Pahari

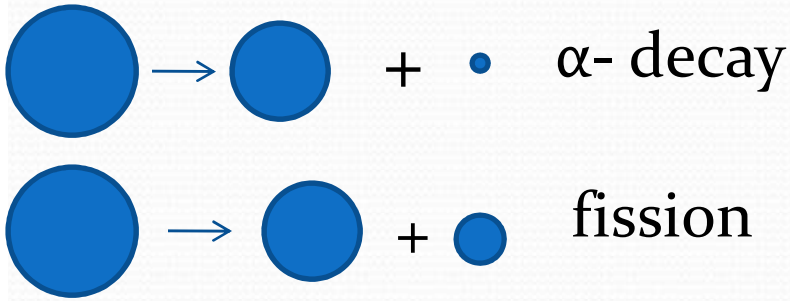
Name of the Department: Physics

Beta decay
Energetic of Beta Decay



Stable state is the minimum energy state of the nucleus.

For very heavy nuclei



$$ {}^{A}_{Z}X \rightarrow {}^{A}_{z+1}Y + {}^{0}_{-1}e $$

β^- Decay

$$ {}^{A}_{Z}X = {}^{A}_{z-1}Y + {}^{0}_{+1}e $$

β^+ Decay

$$ {}^{A}_{Z}X + e^- \rightarrow {}^{A}_{z-1}Y $$

Electron capture

- Energetics of β− decay:

For β− decay $ {}^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e $

The disintegration energy in $\beta^{-}\ decay$

$$Q_{\beta^-} = [M_n(A,Z) - M_n(A,Z+1) - m_e]C^2$$

where $M_n(A,Z)$ and $M_n(A,Z+1)$ are the Nuclear masses of X and Y, m_e is the electronic mass.

In atomic masses

$$Q_{\beta^-} = [M(A,Z) - Zm_e - M(A,Z+1) + (z+1)m_e - m_e]C^2$$

$$Q_{\beta^-} = [M(A,Z) - M(A,Z+1)]C^2$$

$$Q_{\beta^-} = [M(A,Z) - M(A,Z+1)]$$ In energy unit

$$Q_{\beta^-} > 0; \quad if\ M(A,Z) > M(A,Z+1)$$

This implies that $\beta^-\ decay$ occurs only if the mass of the parent atom is greater than that of the daughter atom.

- Energetic of β^+ decay:

For β^+ decay ${}^{A}_{Z}X = {}^{A}_{Z-1}Y + {}^{0}_{+1}e$

The disintegration energy in β^+ decay

$$Q_{\beta+} = [M_n(A,Z) - M_n(A,Z-1) - m_e]C^2$$

In atomic masses

$$Q_{\beta+} = [M(A,Z) - Zm_e - M(A,Z-1) + (z-1)m_e - m_e]C^2$$

$$Q_{\beta+} = [M(A,Z) - M(A,Z-1) - 2m_e]C^2$$

$$Q_{\beta+} = [M(A,Z) - M(A,Z-1) - 2m_e]$$

In energy unit

$$Q_{\beta+} > 0; \quad if\ M(A,Z) > M(A,Z-1) + 2m_e$$

Which implies that β^+ decay is possible if the mass of the parent atom is greater than that of the daughter atom by at least twice the electronic mass.

Since the electron has a rest energy of 0.511 Mev. So, to possible the disintegration the mass of parent atom must be Greater than that of the daughter atom by an amount at least equal to 1.022Mev.

Orbital electron capture:

$$ {}^{A}_{Z}X + e^{-} \rightarrow {}^{A}_{z-1}Y $$

$$ p + e^{-} \rightarrow n \qquad n \rightarrow n + 1 \quad Z \rightarrow Z - 1 $$

The disintegration energy in E.C

$$ Q_e = [M_n(A,Z) + m_e - M_n(A,Z-1)]C^2 - B_e $$

$$ Q_e = [M(A,Z) - Zm_e + m_e - M(A,Z-1) + (z-1)m_e]C^2 - B_e $$

$$ Q_e = [M(A,Z) - M(A,Z-1)]C^2 - B_e $$

$$ Q_e = [M(A,Z) - M(A,Z-1)] - B_e $$

In energy unit

$$Q_e > 0; \quad if\ M(A,Z) > M(A,Z-1) + B_e$$

This implies that the electron capture is possible if, and only if, the mass of the parent atom is grater than that of the daughter atom by at least the binding energy of the electron.

If B_e is small, the condition simply reduces to

$$M(A,Z) > M(A,Z-1)$$

E.C and β^+ decay can occur in same nucleus.

The decay Beryllium to Lithium

$$^{7}_{4}Be + e^{-} \rightarrow {}^{7}_{3}Li$$

The difference in the atomic masses of the two nuclei is 0.864 Mev, which is less than $2m_eC^2 = 1.022$Mev

The decay Bromine to Selenium

$$^{80}_{35}Br \rightarrow {}^{80}_{34}Se + \beta^+$$

$$^{80}_{35}Br + e^{-} \rightarrow {}^{80}_{34}Se$$

The atomic mass difference between he two nuclei is 2.66 Mev , which is greater than $2m_eC^2$.