Part I

# NUCLEAR PHYSICS

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## MASS DEFECT

Mass Defect = $M_{expected} - M_{observed}$

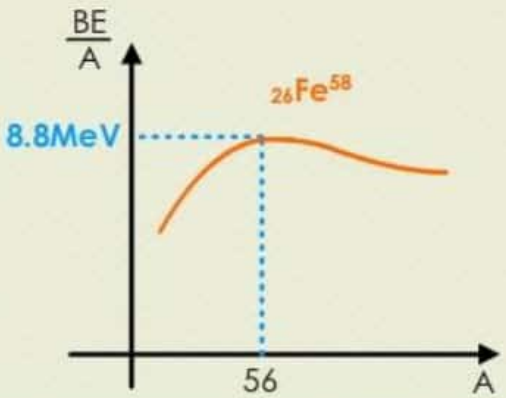
$\Delta m = [Zm_p + (A - Z)m_n - [M_{atom} - Zm_e]$

## BINDING ENERGY

It is the minimum energy required to break the nucleus into its constituent particles.

Binding Energy (B.E.) = $\Delta mc^2 = \Delta m \times 931$ MeV

- Binding energy per nucleon is more for medium nuclei than for heavy nuclei. Hence, medium nuclei are highly stable.
- *The heavier nuclei* being unstable have tendency to split into medium nuclei. This process is called **Fission**.
- *The Lighter nuclei* being unstable have tendency to fuse into a medium nucleus. This process is called **Fusion**.




## RADIOACTIVITY

- It was discovered by **Henry Becquerel**.
- Spontaneous emission of radiations ($\alpha$, $\beta$, $\gamma$) from unstable nucleus is called **radioactivity**. Substances which show radioactivity are known as **radioactive substance**.
- ***In radioactive decay,*** an unstable nucleus emits $\alpha$ particle or $\beta$ particle. After emission of $\alpha$ or $\beta$ particle the remaining nucleus may emit $\gamma$- particle, and convert into a more stable nucleus.

### $\alpha$- particle

It is a doubly charged helium nucleus. It contains two protons and two neutrons.

Mass of $\alpha$ - particle = Mass of $_2H$ $e^4$ atom $- 2m_e = 4\ m_p$

Charge of $\alpha$ - particle = + 2e

### $\beta$- particle

**$\beta^-$ (electron)**

Mass = $m_e$ : Charge = $-$ e

**$\beta^+$ (positron)**

Mass = $m_e$ : Charge = + e

positron is an antiparticle of electron.

### $\gamma$- particle

They are energetic photons of energy of the order of **MeV** and having zero rest mass.

# RADIOACTIVE DECAY (DISPLACEMENT LAW)

## 1 α - DECAY

$$_ZX^A \rightarrow {}_{Z-2}Y^{A-4} + {}_2He^4 + Q$$


**Q value** is definied as energy released during the decay process.

Q value = rest mass energy of reactants − rest mass energy of products

Let, $M_x$ = mass of atom $_ZX^A$, $M_y$ = mass of atom $_{Z-2}Y^{A-4}$, $M_{He}$ = mass of atom $_2He^4$

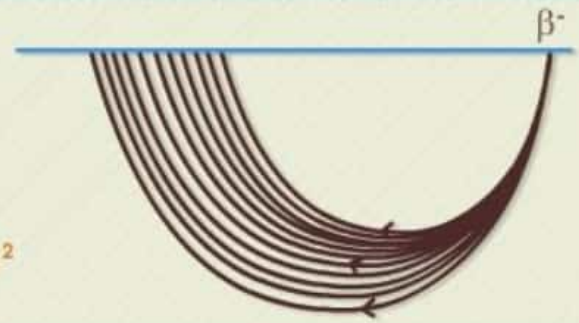
$$\text{Q value} = [M_x - M_y - M_{He}]c^2$$

## 2 $\beta^-$ - DECAY

$$_ZX^A \rightarrow {}_{Z+1}Y^A + {}_{-1}e^0 + Q$$

$$T_e = \frac{m_y}{m_e + m_y} Q, \quad T_y = \frac{m_e}{m_e + m_y} Q,$$

$$\text{Q value} = [M_x - \{(M_Y - m_e) + m_e\}]\, c^2 = [M_x - M_y]c^2$$




## 3 $\beta^+$ - DECAY

$$_ZX^A \rightarrow {}_{Z-1}Y^A + {}_{+1}e^0 + \nu + Q$$

$$\text{Q value} = [M_x - \{(M_Y + m_e) + m_e\}]\, c^2 = [M_x - M_y - 2M_e]c^2$$

# RADIOACTIVE DECAY : STATISTICAL LAW

- Rate of radioactive decay is directly proportional to N
- where N = number of active nuclei.
- Rate of radioactive decay of $A = \frac{-dN}{dt} = \lambda N$
- where $\lambda$ = decay constant of the radioactive substance.
- Number of nuclei decayed (i.e., the number of nuclei of B formed)

$$N = N_0(1 - e^{-\lambda t})$$

## 1 HALF LIFE ($T_{1/2}$)

$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}$$

## 2 ACTIVITY

Activity is defined as the rate of radioactive decay of nuclei

$$A = A_0 e^{-\lambda t}$$

## 3 AVERAGE LIFE

$$T_{avg} = \frac{\text{sum of ages of all the nuclei}}{N_0} = \frac{\int_0^\infty \lambda N_0 e^{-\lambda t} dt \,.t}{N_0} = \frac{1}{\lambda}$$