Chapter-13: Nuclei

Discovery of neutrons:

In 1932, James Chadwick bombarded α particles on Be nucleus and found that highly penetrating radiations were emitted out.

These radiations consisted of particles which could not be deflected by electric and magnetic field

These particles could knock off protons from higher elements like He.

This led him to conclude that these particles have mass almost the same as that of protons and are neutral in nature. He named these particles as neutrons.

$$_2He^4 + {}_4Be^9 \longrightarrow {}_6C^{12} + \text{radiations}$$

PROPERTIES OF NEUTRON:

(i) Mass of a neutron $= m_n = 1.67 \times 10^{-24}$ kg.

(ii) As it is neutral, it is highly penetrating in nature.

(iii) It is not deflected by electric or magnetic field.

(iv) Inside the nucleus it is stable but outside the nucleus it decays as:

$$n \longrightarrow p + e^- + \bar{\nu} \;;\; (\bar{\nu} = \text{anti neutrino})$$

mass-less, charge-less

(v) Half life = 12 mins

Mean life = 1000 seconds.

Characteristic features of a nucleus:

1) Any element can be represented as $_{Z}X^{A}$

$Z \rightarrow$ atomic no. (no. of protons (or) electrons)

$A \rightarrow$ atomic mass (no. of protons + no. of neutrons)

$X \rightarrow$ element.

2) Size of the nucleus

$$\text{Radius} = R = R_0 A^{1/3} \quad ; \quad R_0 = 1.2 \times 10^{-15} \, m$$

3) Volume of the nucleus

$$\text{Volume} = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A.$$

4) $$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{3 m_n \cancel{A}}{4\pi R_0^3 \cancel{A}} = \frac{3 m_n}{4\pi R_0^3} = 2.7 \times 10^{17} \, kg/m^3$$

Hence density of all nuclei is a constant.
It is higher than density of ordinary matter,
eg: density of $H_2O = 1000 \, kg/m^3$.

Mass defect:

The difference between total mass of all the nucleons and the actual measured mass of the nucleus.

experimentally obtained mass

$$\Delta m = [Z m_p + (A-Z) m_n] - M_x$$

Binding energy: The energy released when the constituents of the nucleus bind together to form the nucleus (or) The energy supplied to break the nucleus into its constituents. (Energy equivalent to mass defect)

$$B.E = \Delta m c^2$$

$$\Delta m = 1.67 \times 10^{-27} \, kg$$

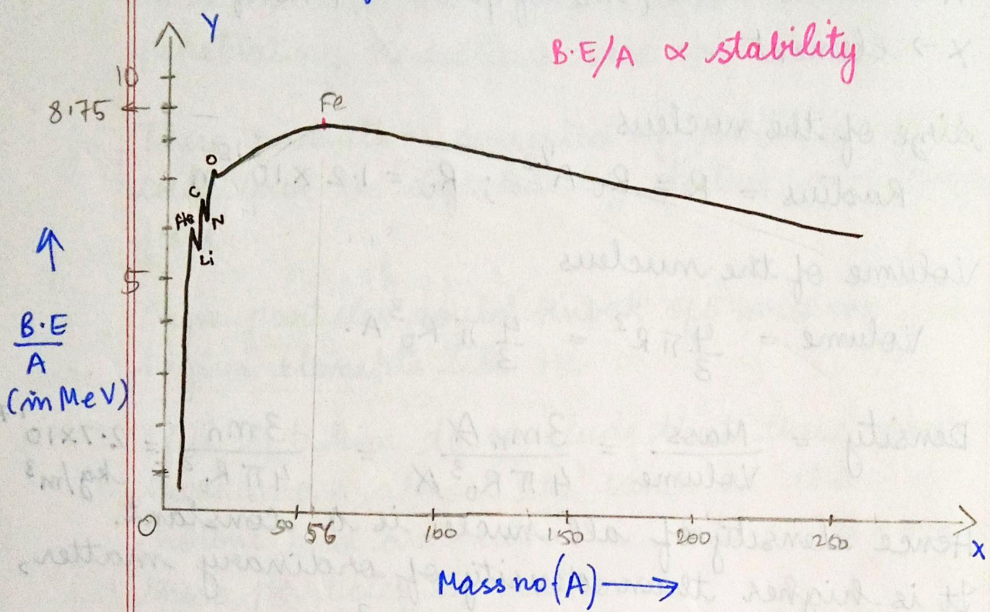
$$BE = \frac{(1.67 \times 10^{-27})(3 \times 10^{8})^2}{1.6 \times 10^{-13}} = 931 \, MeV$$

$$\boxed{\therefore B.E = 931 \, MeV}$$

Binding energy per nucleon = $\frac{\text{Total B.E}}{\text{Mass no.}}$

Variation of B·E/A with mass no. A:

B·E/A ∝ stability



- For Fe, B·E/A = 8·75 MeV, it is the most stable of all elements.
- The peaks in the graph corresponding to the nuclei having mass number in the multiples of 4 (He, C, O) have more B·E/A than their immediate neighbours.
- A less than 30, A > 170 ⇒ B·E/A is less, indicating that they are less stable.
- A = (30 − 170) ⇒ B·E/A is a constant as the strong nuclear force between the nucleons is a short range force showing saturation property (Refer Pg- 444)

Nuclear fission: (To attain stability)

Heavier elements like Uranium have less B.E/A, hence they are less stable. So they undergo nuclear fission reactions to form products which have more B.E/A and hence are more stable.

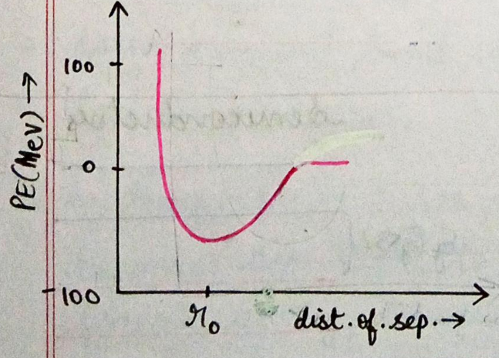
Nuclear fusion: (To attain stability)

Lighter elements like Hydrogen have less B.E/A, and so they are less stable. Hence they undergo nuclear fusion reactions to form products which have more B.E/A and hence are more stable.

Properties of strong nuclear force:

- It is a charge independent force (same bet. p-p, p-n, n-n)
- It is attractive in nature.
- It does not obey inverse square law.
- It is spin-dependent.
- It is a short range force, showing saturation property.

Variation of PE bet. 2 nucleons with distance



$r_0 = 0.8$ fm

$= 0.8 \times 10^{-15}$ m

$r < r_0$ = repulsive force

$r > r_0$ = attractive force