2024 – 25

Nuclei

Recall what did you study in previous class

Nucleus

- The atomic nucleus is the small, dense region consisting of protons and neutrons at the center of an atom.
- **Atomic Number (Z):** Number of protons in a nucleus.
- **Mass Number (A):** Number of protons + neutrons.
- **Properties of Nucleus:**
  Radius of nucleus, R = R0 A1/3 (Where R0 = 1.2 × 10–15m)

  Volume of Nucleus, $V = \frac{4\pi R_0^3 A}{3}$

  Density of Nucleus, $d = \frac{m}{v} = \frac{3m}{4\pi R_0^3} = 2.3 \times 10^7$ Kg/m^3

Mass Energy Equivalence Relation

- According to Einstein; [$E = mc^2$]
  1 amu = 1.66×10^{-27} kg = 931.5 MeV
  (where E is total energy of mass m, c is speed of light)

Mass Defect: It is difference between total mass of nucleons and nucleus.

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

Binding Energy: The Energy required to bring the nucleons from infinity to form the nucleus.

Binding Energy = $(\Delta m) \times 931.5$ MeV

Packing fraction = $\frac{\text{Mass excess}}{\text{Mass number}}$

Nuclear Force

- Strongest force in nature.
- Short range force.
- Charge independent.
- Depends on spin or angular moment of nuclei.
- Non-central force.

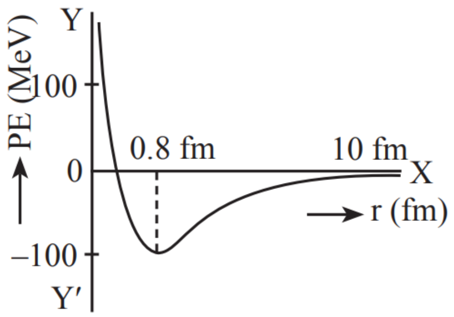
Plot of Potential Energy Vs Distance

Important Features:

Attraction is maximum at $r_0 = 0.8$ fm

For $r < r_0$, Force is repulsive.

For $r > r_0$, Force is attractive.



Radioactivity

Radioactive Decays: Generally, there are three types of radioactive decays

(i) α decay

(ii) β^- and β^+ decay

(iii) γ decay

α decay: By emitting a particle, the nucleus decreases it's mass number and move towards stability. Nucleus having $A > 210$ shows a decay.

β decay: In beta decay, either a proton is converted into neutron and position (β^+) or neutron is converted into proton and electron (β^-)

γ decay: When an α or β decay takes place, the daughter nucleus is usually in higher energy state, such a nucleus comes to ground state by emitting a photon or photons called as γ-rays.

Order of energy of γ photon is 100 keV

Average life $t_{av} = \frac{1}{\lambda}$

Activity $R = \lambda N = R_0 e^{-\lambda t}$

Units of activity 1Bq = 1 decay/s,

1 curie $= 3.7 \times 10^{10}$ Bq,

1 rutherford $= 10^6$ Bq

After n half live Number of nuclei left $= \frac{N_0}{2^n}$

Probability of a nucleus for survival of time $t = \frac{N}{N_0} = \frac{N_0 e^{-\lambda t}}{N_0} = e^{-\lambda t}$

Nuclear Fission

- By bombarding a particle on a heavy nucleus ($A > 230$), it splits into two or more light nuclei. In this process certain mass disappears which is obtained in the form of energy (enormous amount)
  $A + p \rightarrow B + C + Q$

Nuclear Fusion

It is the phenomenon of fusing two or more light nuclei to form a single heavy nucleus.

$A + B \rightarrow C + \text{Energy}$

The product (C) is more stable then reactants (A and B) and $m_c < (m_a + m_b)$ and mass defect $D_m = [(m_a + m_b) - m_c]$ amu Energy released is $E = (\Delta m)\ 931$ MeV