Chapter-13: Nuclei

1. **Composition of nucleus**:
Nucleus is composed of two types of particles-(i) proton (positively charged particles) and (ii) neutrons, (neutral particles
Mass of neutron is slightly greater than the mass of proton.
Mass of proton, $m_p \approx 1840 m_e$ where m_e = mass of electron = 9.1 X 10^{-31} kg $\approx 0.0009 \times 10^{-27}$kg
Mass of proton $m_n = 1.6725 \times 10^{-27}$kg, (mass of neutron $m_n = 1.6747 \times 10^{-27}$kg)

2. **Atomic number**
Atomic number of an element is the number of proton inside the nucleus of a neutral atom. It is also equal to number of electrons revolving in various orbits around the nucleus of the atom. It is represented by Z. So, **Z = no. of proton = no. of electron**

3. **Mass number (A):**
The total number of neutrons and protons is called mass number. A chemical symbol or element is represented as ${}_Z^4X$ where X is any element. Total charge of nucleus is Ze, where e the charge on proton.

4. **Nuclear size**:
The volume of a nucleus is proportional to it mass number.$\frac{4}{3}\pi R^3 \propto A \quad (R\ is\ the\ radius\ of\ nucleus)$ $\therefore\ R \propto A^{\frac{1}{3}}\ or\ R = R_0 A^{\frac{1}{3}}$

R_0 is a constant= range of nuclear size. It is known as nuclear unit radius and its value is 1.2 x 10^{-15} m (1.2 fm).Hence, different nuclei of different elements have different size.

5. **Nuclear Density:**
It is the ratio of mass of nucleus to the volume of nucleus.
Let m be the average mass of nucleons (1.67 X 10^{-27} kg) and R is the radius of nucleus. If 'A' is the mass number of element, then $\rho = \frac{mA}{\frac{4}{3}\pi R^3} = \frac{3m}{4\pi {R_0}^3} \quad (R^3 = {R_0}^3 A)$
Thus, the density of a nucleus is constant and is independent of mass number A for all nuclei and ρ is found to be 2.3 x 10^{17} kg/m^3. Hence, matter in the nucleus is very densely packed.

6. **Nuclide**: It is a specific nucleus of an atom which is characterised by its atomic number Z and mass number A. example, ${}_{16}^{32}S$ together taken as one nuclide.

7. **Isotopes, Isobars and Isotones**
Isotopes: Atoms having same atomic number (Z) but different mass number (A).
For example, ${}_{92}^{235}U, {}_{92}^{238}U$. ${}_1^1H$, ${}_1^2H$, ${}_1^3H$, ${}_8^{16}O, {}_8^{17}O$, ${}_8^{18}O$; ${}_2^3He$, ${}_2^4He$
Isobars: Atoms having same mass number (A) but different atomic number (Z)
For example,
Isotones: Nuclei containing same number of neutrons are called isotones. ${}_{17}^{37}Cl, {}_{19}^{39}K$.

8. **Atomic mass unit and energy equivalent to it**
A unit in which atomic and nuclear masses are measured is called atomic mass unit (u).
1 u = $\frac{1}{12}th$ of mass of an atom of ${}_6^{12}C$ isotope of carbon. 1 u (or 1 amu) = 1.66 x 10^{-27} kg.
1 u (or amu) represents the average mass of a nucleon.
1 eV = 1.602 x 10^{-19} J, 1u mass has energy 931.5 MeV.

9. **Mass defect** (Δm) = (sum of masses of neutrons and protons, or mass of nucleon) – actual mass of the nucleus
Certain mass disappears in the formation of a nucleus in the form of mass defect. That is,

$Zm_p + (A - Z)m_n - m_N$= mass defect. This mass loss appears in the form of energy (Einstein theory of mass-energy equivalence) called Binding Energy.

10. **Binding energy:**. Thus, binding energy is the minimum energy required to separate its nucleon and place them at rest at infinite distance apart. Or, it is defined as the energy equivalent to the mass defect of the nucleus.
$Binding\ energy = \Delta mc^2 = \left[Zm_p + (A - Z)m_n - m_N\right]c^2$. This binding energy is expressed in joule when Δm is in kg.
If Δm is measured in amu, then binding energy, $E_b = \Delta m\ amu = \{Zm_p + (A - Z)m_n - m_N\}$ = $\Delta m \times 931$MeV$where, Mass\ of\ nucleus\ or\ mass\ of\ atom, m_N = [m({}^A_Z X)]$
Here, m_p is the mass of proton and m_n is the mass of neutron.

$$Binding\ energy\ per\ nucleon, E_{be} = \frac{Total\ binding\ energy, E_b}{Mass\ number, A}$$

So, the higher the binding energy per nucleon, the larger will be stability.