# Nuclei

- The unit in which atomic and nuclear masses are measured is called atomic mass unit (amu).

- One amu is defined as 1/12th of the mass of an atom of $_6C^{12}$ isotope.

  i.e., 1 amu = 1.66×10-27 kg

- Atomic masses can be measured using a mass spectrometer.

- The different types of atoms of the same element which exhibit similar chemical properties, but have different masses are called isotopes.
- Isotopes are the atoms of an elements whose nuclei have the same number of protons, but have different number of neutrons.
- Isobars are the nuclei with the same mass number (A), but with different atomic numbers.
- Isotones are the atoms of different elements with the same atomic weight, but with different atomic numbers.

**Nucleus**

- The nucleus has the positive charge possessed by the protons. For an element of atomic number $Z$, the total charge on an atomic electron is $(-Ze)$, while the charge of the nucleus is $(+Ze)$.

- The composition of a nucleus is described using the followings terms and symbols:

  $Z$ = atomic number = number of protons

  $N$ = neutron number = number of neutrons

  $A$ = mass number = $Z + N$ = total number of protons and neutrons

**Nuclear Size:**

- $R = R_0 A^{\frac{1}{3}}$

Where,

$R \rightarrow$ Radius of the nucleus

$R_0 \rightarrow$ Empirical constant, whose value is found to be $1.2 \times 10^{-15}$ m

$A \rightarrow$ Mass number

**Nuclear Binding Energy:**

- The nuclear mass $M$ is always less than the total mass $\sum m$ of its constituents. The difference between the mass of a nucleus and its constituents is called the mass defect.

$$\Delta M = \left[ Zm_p + (A - Z) m_n \right] - M$$

- Using Einstein's mass–energy relation, we express this mass difference in terms of energy as $\Delta E_b = \Delta M c^2$
- The energy $\Delta E_b$ represents the binding energy of the nucleus. In the mass number range $A$= 30 to 170, the binding energy per nucleon is nearly constant, about 8 $MeV$/nucleon.

**Nuclear Forces:**

Strong forces of attraction which hold together the nucleons (neutrons and protons) in the tiny nucleus of an atom, in spite of strong electrostatic forces of repulsion between protons

- Nuclear forces are independent of charge.
- Nuclear forces are the strongest forces in nature.
- Nuclear forces are very short-range forces.

- Nuclear forces are non-central, non-conservative forces, not obeying inverse square law.

- **Law of radioactive decay:**

$$N(t) = N(0)e^{-\lambda t}$$

Where, $\lambda$ is the decay constant or disintegration constant

- The half life $T_{1/2}$ of a radionuclide is the time in which $N$ has been reduced to one-half of its initial value. The mean life $\tau$ is the time at which $N$ has been reduced to $e^{-1}$ of its initial value.

$$T_{1/2} = \frac{\ln 2}{\lambda} = \tau \ln 2$$

- **Alpha decay:** The phenomenon of emission of an $\alpha$ particle from a radioactive nucleus

$$_{Z}X^{A} \longrightarrow {}_{Z-2}Y^{A-4} + \underset{\text{Alpha particle}}{{}_{2}\mathrm{He}^{4}} + \underset{\text{Energy released}}{Q}$$

- **Beta Decay:** The phenomenon of emission of an electron from a radioactive nucleus

$$_{Z}X^{A} \longrightarrow {}_{Z+1}Y^{A} + {}_{-1}e^{0} + Q$$

- **Gamma Decay:** The phenomenon of emission of a gamma ray photon from a radioactive nucleus

$$_{Z}X^{A} \longrightarrow {}_{Z}X^{A} + \gamma$$

- Einstein's mass-energy relation and is given as $\Delta E = \Delta Mc^2$
- **Nuclear Fission**: A reaction in which a heavy nucleus breaks into two small nuclei with the liberation of energy is known as nuclear fission.
    - Example: ${}_0^1n + {}_{92}^{235}U \rightarrow {}_{92}^{236}U \rightarrow {}_{56}^{144}Ba + {}_{36}^{89}Kr + 3{}_0^1n$
- A continuous nuclear fission reaction is called a **chain reaction**.
- When the fission neutrons are built up to a level and the number of fission producing neutrons is kept constant, then it is known as **controlled chain reaction**.
- **Nuclear reactors** work on the principle of controlled chain reaction.
- **Critical Size**: The minimum size of fissionable material required to sustain a nuclear fission chain reaction.
- **Nuclear** F**usion:** A reaction in which two light nuclei combine to form a heavy nulei with the liberation of energy is known as nuclear fusion.
    - Example: ${}_1^2H + {}_1^2H \rightarrow {}_1^3H + \text{Energy}$
- The energy produced per unit mass in nuclear fusion is higher that that of nuclear fission.

**Radiation Hazards**

- Radiations are dangerous to both human health and the environment
- Gamma radiations and X rays are highly penetrative and cause serious to the DNA and may lead to cancer, genetic defects and birth defects.
- UV rays cause skin burns, premature cataract and skin cancer