

## Nuclei

- The unit in which atomic and nuclear masses are measured is called atomic mass unit *amu*.
- One amu is defined as  $1/12^{\text{th}}$  of the mass of an atom of  ${}_6\text{C}^{12}$  isotope.

$$\text{i.e., } 1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$$

- 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  $1.2 \times 10^{-15} \text{ m}$

$A \rightarrow$  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.

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

- Using Einstein's mass–energy relation, we express this mass difference in terms of energy as  $\Delta E_b = \Delta Mc^2$
- The energy  $E_b$  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  $8 \text{ MeV/nucleon}$ .

### 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:**

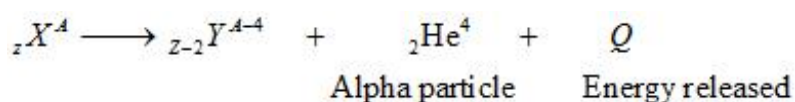
$$N(t) = N(0)e^{-\lambda t}$$

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

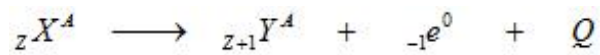
- The half life  $T_{1/2}$  of a radionuclide is the time in which  $N$  has been reduced to one-half of its initial value. The mean life  $t$  is the time at which  $N$  has been reduced to  $e^{-1}$  of its initial value.

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

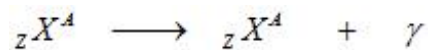
- Alpha decay:** The phenomenon of emission of an  $\alpha$  particle from a radioactive nucleus



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



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



- Einstein's mass-energy relation and is given as  $\Delta E = \Delta M c^2$
- **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:  ${}_0^1 n + {}_{92}^{235} \text{U} \rightarrow {}_{92}^{236} \text{U} \rightarrow {}_{56}^{144} \text{Ba} + {}_{36}^{89} \text{Kr} + 3{}_0^1 n$
- 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 Fusion:** A reaction in which two light nuclei combine to form a heavy nuclei with the liberation of energy is known as nuclear fusion.
  - Example:  ${}_1^2 \text{H} + {}_1^2 \text{H} \rightarrow {}_1^3 \text{H} + \text{Energy}$
- The energy produced per unit mass in nuclear fusion is higher than 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