

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 element 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 following 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 ΔE_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:**

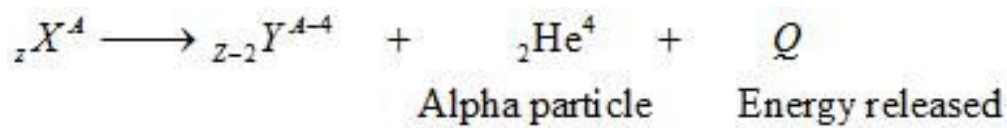
$$N(t) = N(0)e^{-\lambda t}$$

Where, λ is the decay constant or disintegration constant

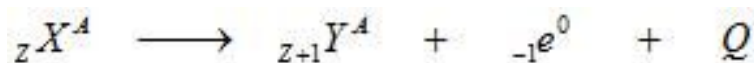
- The half life $T_{1/2}$ of a radionuclide is the time in which N has been reduced to one-half of its initial value. The mean life τ is the time at which N has been reduced to e^{-1} of its initial value.

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

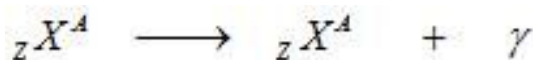
- **Alpha decay:** The phenomenon of emission of an α particle from a radioactive nucleus



- **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 $\Delta E = \Delta Mc^2$
- **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: ${}_0^1\text{n} + {}_{92}^{235}\text{U} \rightarrow {}_{92}^{236}\text{U} \rightarrow {}_{56}^{144}\text{Ba} + {}_{36}^{89}\text{Kr} + 3{}_0^1\text{n}$
- 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 damage to the DNA and may lead to cancer, genetic defects and birth defects.
- UV rays cause skin burns, premature cataract and skin cancer