PHYSICS

CLASS NOTES FOR CBSE

Chapter 29. Nuclei

01. Introduction

We shall now study the constituents of the nucleus and how they are held together. We shall discuss various properties of nuclei such as size, mass, density and stability of nuclei and associated nuclear phenomena such as radioactivity, nuclear fission and nuclear fusion.

02. Atomic Masses

The unit in which atomic and nuclear masses are measured is called **atomic mass unit** (a.m.u.)

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

As Avogadro's number $= 6.023 \times 10^{23}$,

$\therefore$ Mass of 6.023×10^{23} atoms of $C^{12} = 12\,g$

Mass of one atom of $C^{12} = \dfrac{12}{6.023 \times 10^{23}} g$

By definition, 1 a.m.u. $= \dfrac{1}{12} \times$ mass of one atom of C^{12}

$\therefore$ 1 a.m.u. $= \dfrac{1}{12} \times \dfrac{12}{6.023 \times 10^{23}} g = 1.66 \times 10^{-24} g$

$1\,a.m.u. = 1.66 \times 10^{-27}\,kg$

As an atom of ${}_6C^{12}$ contains 12 nucleons, therefore, *one a.m.u. represents the average mass of a nucleon and is denoted by u.*

In terms of this unit, mass of an electron (m_e) = 0.00055 u

mass of proton (m_p) = 1.0073 u

mass of a hydrogen atom = $m_e + m_p$ = 1.0078 u

mass of a neutron (m_n) = 1.0086 u.

Electron volt (eV). *It is the unit of energy.*

One electron volt is the energy gained by an electron, when accelerated through a potential difference of one volt.

Relation between a.m.u. and MeV

According to Einstein, mass energy equivalence is represented by $E = mc^2$

Taking m = 1. a.m.u. $= 1.66 \times 10^{-27} kg.$ and $c = 3.0 \times 10^8\ m/s$

we get, $E = (1.66 \times 10^{-27})(3.0 \times 10^8)^2 J = 1.49 \times 10^{-10} J$

$\therefore \quad E = \frac{1.49 \times 10^{-10}}{1.6 \times 10^{-13}} MeV = 931.25\, MeV$

Hence, 1 a.m.u. $\simeq 931\, MeV$, *which is used as a standard conversion.*

03. Neutron

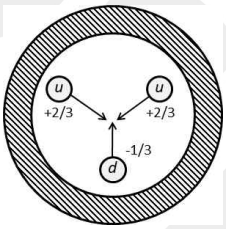
A neutron is a neutral particle carrying no charge and having mass roughly equal to the mass of a proton.

Now the mass of a neutron is known to a high degree of accuracy and is equal to
m_n = 1.00866 u
= 1.6749×10^{-27} kg

04. Composition of Nucleus

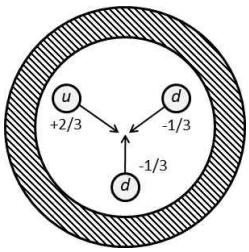
Nuclei are composed of protons and neutrons. Following points should be remembered about protons and neutrons.

Proton :



(i) The nucleus of hydrogen atom is called proton.
(ii) It is an essential constituent of all nuclei.
(iii) It carries **positive charge** = $1.6 \times 10^{-19} C$
(iv) Its mass $= 1.67262 \times 10^{-27} kg = 1.0073\, u$
$= 1836$ times the mass of an electron
(v) Due to its positive charge, protons are not used as projectile in nuclear fission.
(vi) It is stable even outside the nucleus.
(vii) Its qua⁊ content is **uud**.

Neutron:



(i) Neutron was discovered in 1932 by **James Chadwick**.
(ii) It has no charge, hence it is a neutral particle.

(iii) Its mass = $1.67493 \times 10^{-27} kg \simeq$ nearly equal to that of proton
= 1839 times the mass of an electron
= $1.0087\, u$

(iv) It is an essential constituent of all nuclei except hydrogen ($_1H^1$).

(v) It has very high penetrating power because it can neigher be attracted nor repelled by the nucleus.

(vi) A fast moving neutron can be slowed down by materials called moderator. Examples of moderators are heavy water, graphite, paraffin wax etc. Neutrons are in thermal equilibrium with the molecules of the moderator when both attain the same energy. The kinetic energy of a thermal neutron is about 0.04 eV.

(vii) Thermal neutrons are used as projectiles in a nuclear fission.

(viii) Neutron has very low ionising power.

(ix) A free neutron (i.e., outside the nucleus) is unstable and decays into a proton, an electron and an antineutrino.

$_0n^1 \rightarrow {}_1H^1 + {}_{-1}e^0 + \bar{v}$ (antineutrino)

(proton) (electron)

The half life of a free neutron is about 12 minute. The mean life is about 1000 s.

(x) Neutron inside the nucleus is stable.

(xi) The quark content of a neutron is **udd**.

Nucleons : Protons and neutrons taken together are called **nucleons**. We regard, a proton and a neutron as two different charge states of the same particle, called "nucleon".

Mass Number (A) : The total number of nucleons (=neutrons + protons) in the nucleus of the atom is called **mass number of the atom**. It is denoted by A. It is different from the mass of the atom which includes the total mass of neutrons plus protons plus electrons.

Atomic Number (Z) : The total number of protons in the nucleus of an atom is called atomic number of that atom. It is denoted by Z. The arrangement of various elements in the periodic table is according to their atomic numbers.

Let N be the number of neutrons in the nucleus of an atom with A as the mass number and Z as the atomic number.

Then A = N + Z or N = A – Z ...(i)

The nucleus of an atom is denoted by the chemical symbol (X) of the atom with the atomic number Z as the subscript and mass number A as the superscript. hence we write or represent a nuclide/nucleus as

$_Z$(Chemical Symbol)^A or z^{X^A}

For example, nucleus for uranium is $_{92}U^{238}$

It contains 92 protons and 238-92=146 neutrons.

Nuclear charge : Total charge of the nucleus is equal to the total charge on all the Z protons in it = Ze where $e = 1.6 \times 10^{-19} C$.