Salahaddin University
College of Science
Physics Department
3rd Stage Communication Branch
2nd Semester

Nuclear Physics

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References

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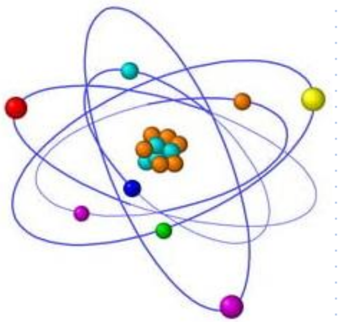
Chapter One:



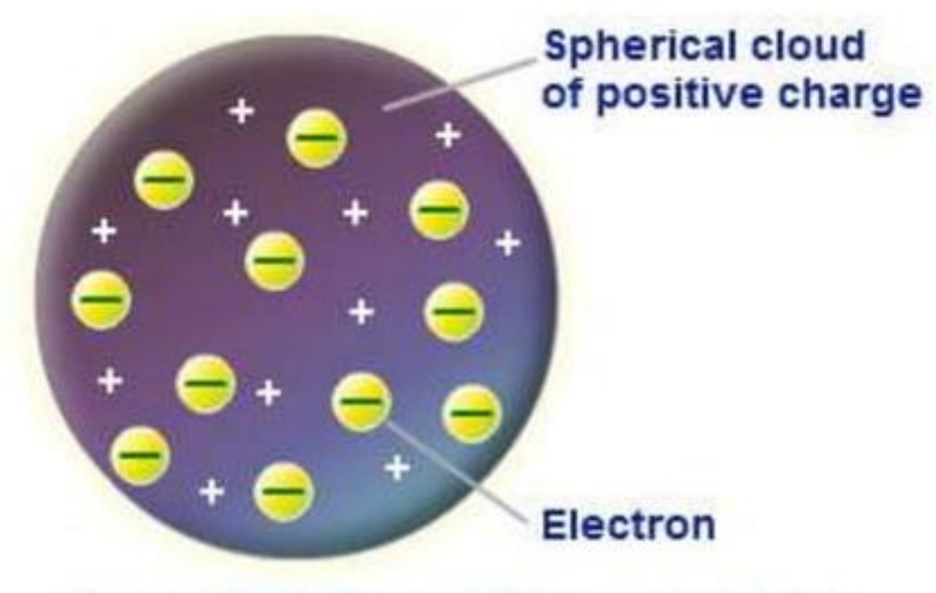
Basic Nuclear physics

Out Line

- ✓Atomic Structure
- ✓Describe Nucleus
- ✓Nuclear mass and charge
- ✓Classification of the Elements
- ✓The Atomic Mass Unit (a.m.u)
- ✓Mass Defect
- ✓Properties of the Nucleus

❖ **According to J. J. Thomson model**

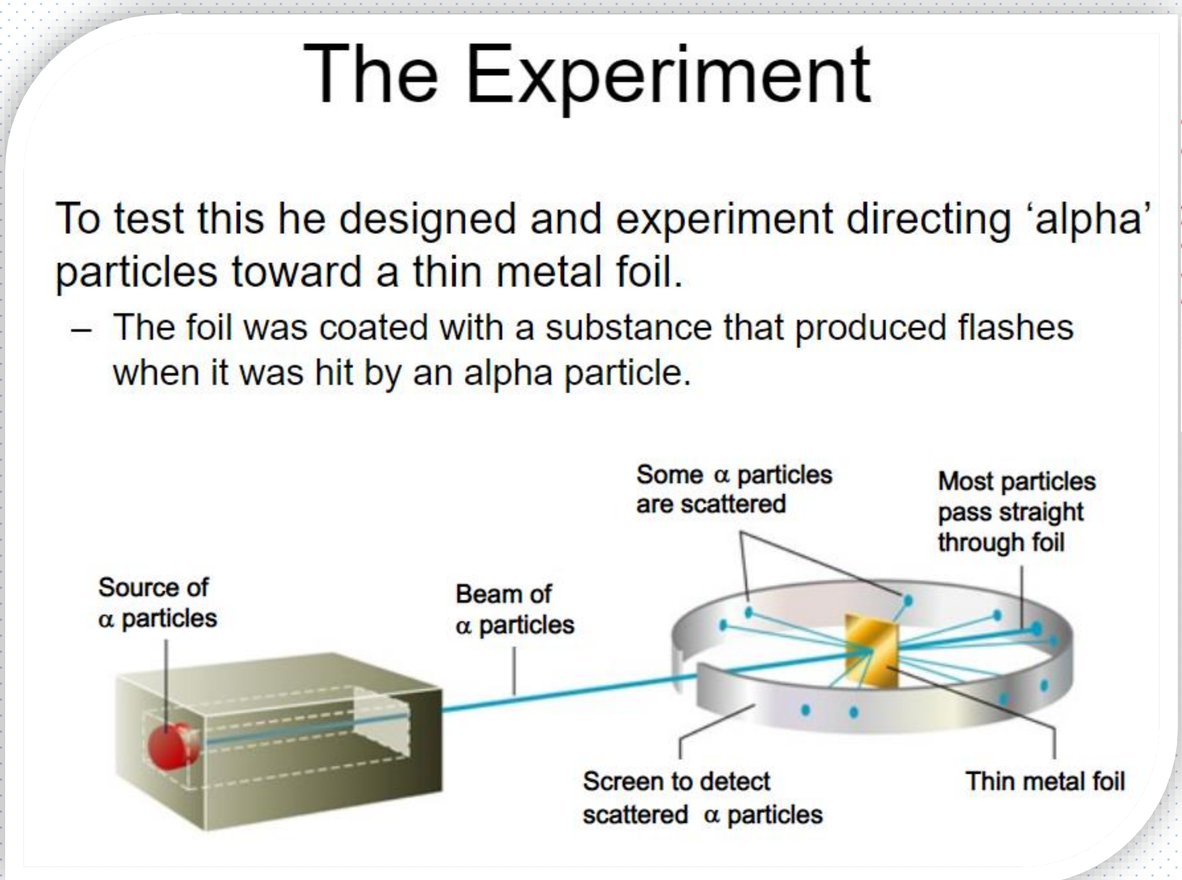
Thomson discovers electrons , believed to reside within a sphere of uniform positive charge (the plum pudding model)

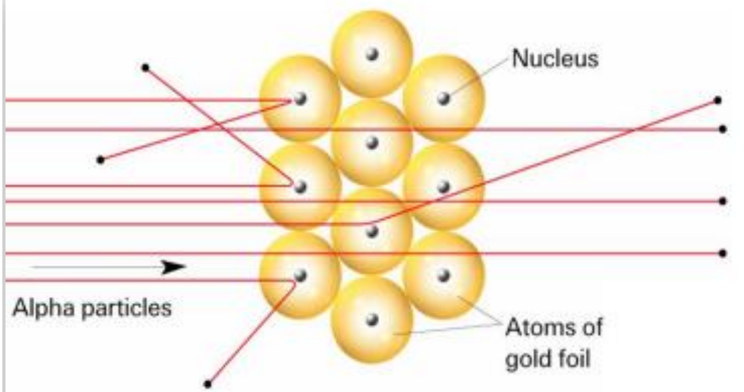


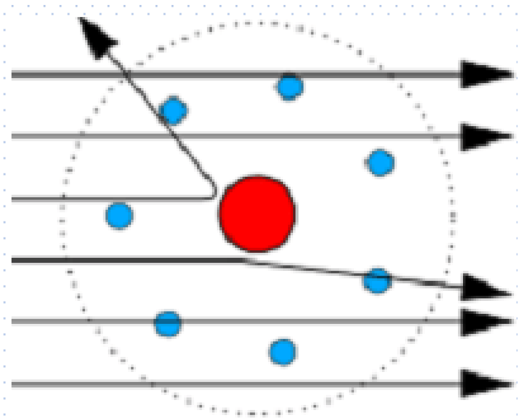
Atomic Structure

❖ According to Rutherford's nuclear model

All the positive charge and almost all of the atom's mass are confined to a tiny volume at the center of the atom, called the nucleus.



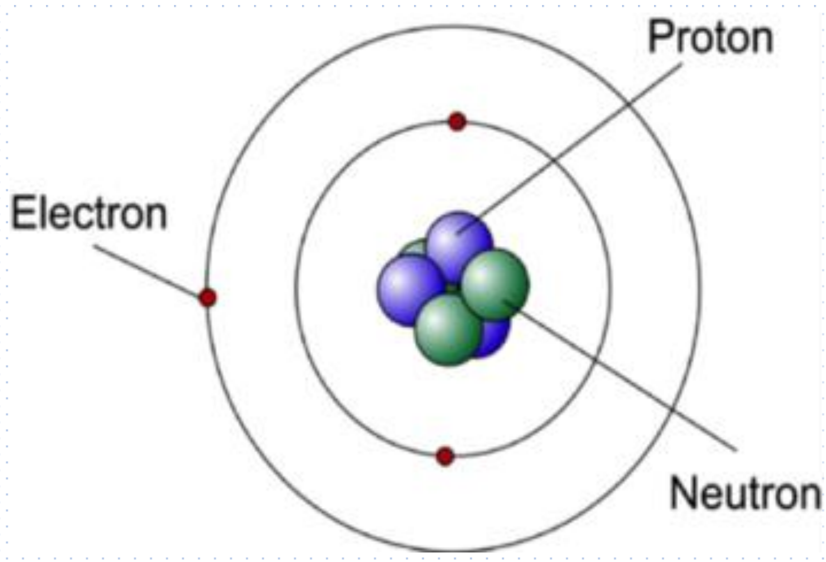




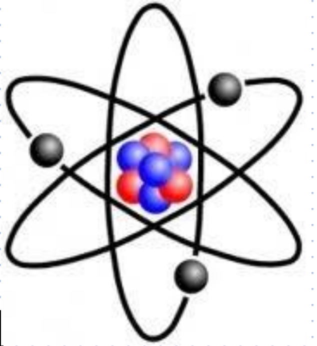
Atomic Structure

- **According to Bohr model**

  The atom consists of a dense nucleus of protons and neutrons (nucleons) surrounded by electrons traveling in discrete orbits at fixed distances from the nucleus

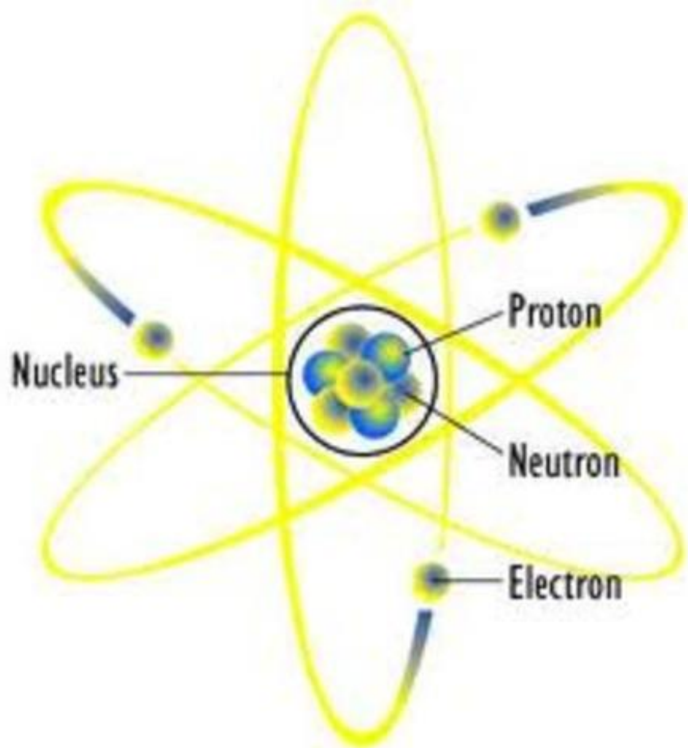


Atomic Structure

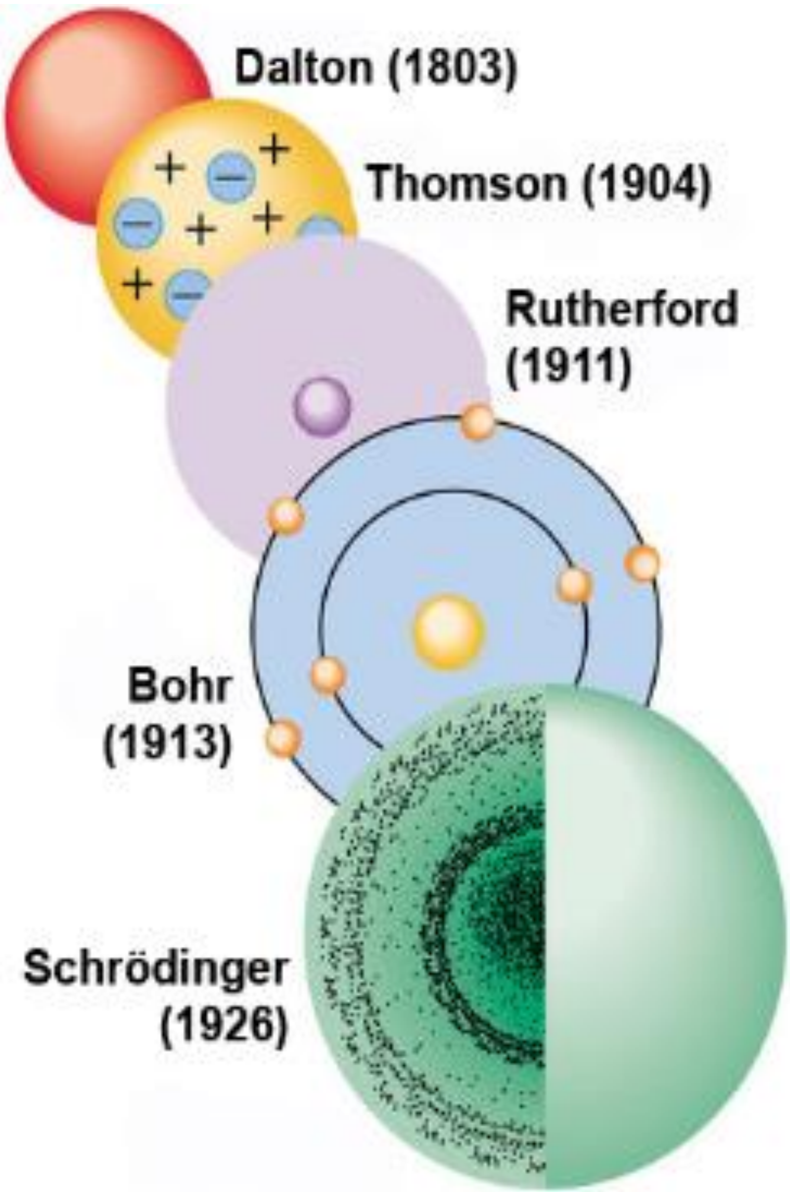


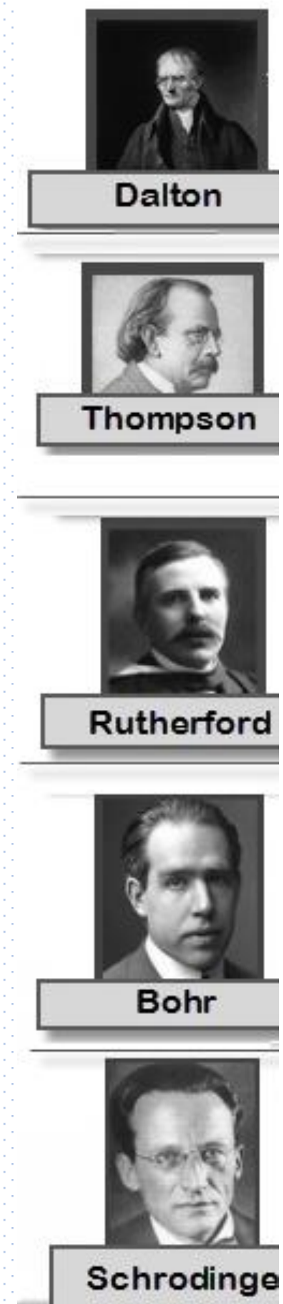
- **According to the Bohr –Sommerfield model**

The path of an electron in an atom is elliptical



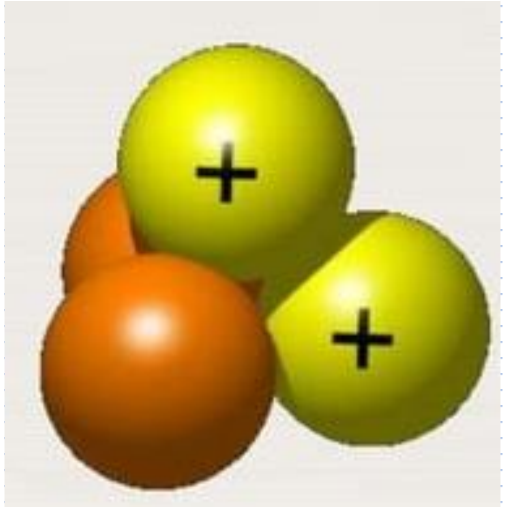
HISTORICAL DEVELOPMENT OF THE MODEL OF ATOMIC THEORY





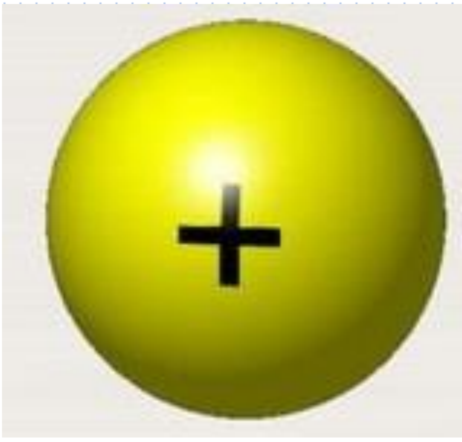
Describe Nucleus

- The nucleus is the central part of an atom. It is composed of protons and neutrons.
- The nucleus determines the identity of element and its atomic mass.
- proton and neutron have essentially the same but only the proton is charged while the neutron has no charge.



Describe Protons

- Protons are positively charged particles found inside the nucleus of an atom.
- Each element has a unique atomic number(a unique number of protons).
- Proton number never changes for any given element. For example, oxygen has an atomic number of 8 indicating the oxygen always has 8 proton.



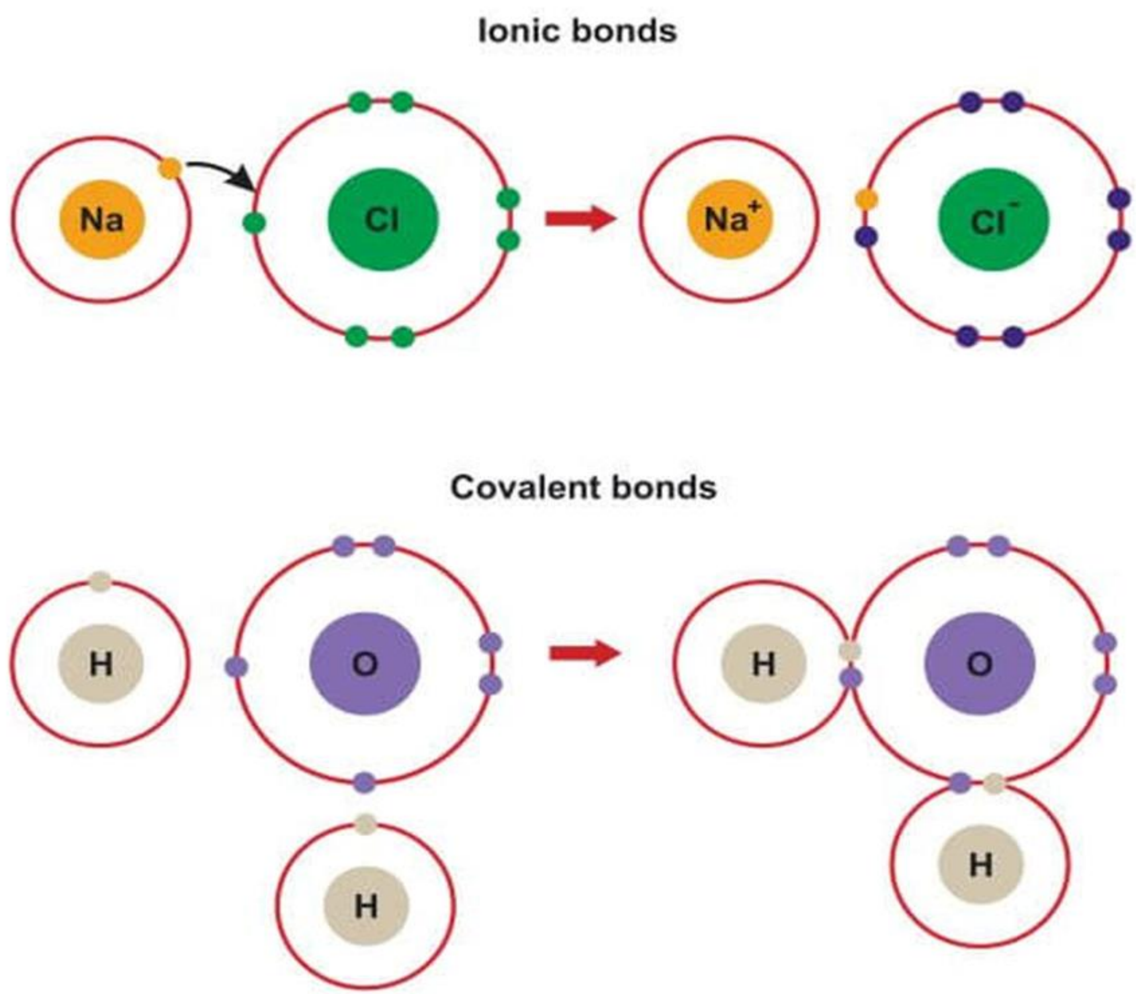
Describe Neutrons

- Neutrons are the other particle found in the nucleus of an atom.
- Unlike protons and electrons ,however, neutrons carry no electrical charge and are thus neutral
- Atoms of a given element do not always contain the same number of neutrons.

Describe Electrons

- ❖Electron are negatively charged particles that surround the nucleus in "orbits".

- ❖The sharing or exchange of electrons between atoms forms chemical bonds is how new molecules and compounds are formed.


Ionic bonds
Na
Cl
Na+
Cl-
Covalent bonds
H
O
H
H
O
H

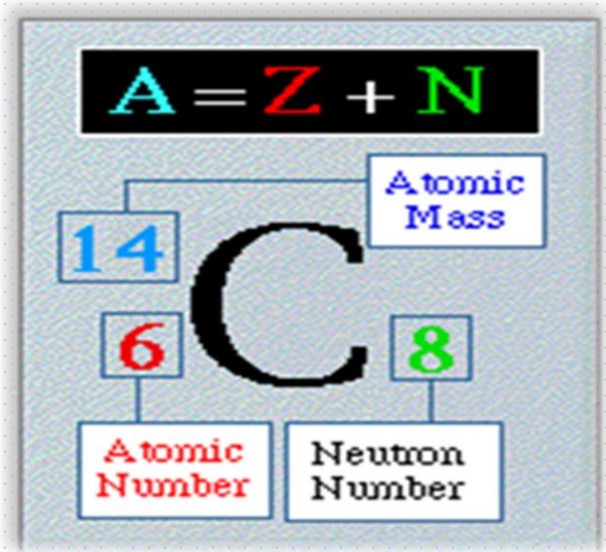
Summary of the Atom

Particle	Symbol	Mass (kg)	Energy (MeV)	Charge
Proton	p	1.672E-27	938.2	+1
Neutron	n	1.675E-27	939.2	0
Electron	e	0.911E-30	0.511	-1

The Atomic Nucleus

The symbol of an atomic nucleus is:

$$ {}^{A}_{Z}X_{N} $$



X = chemical symbol of the element.

Z = atomic number of the element.

= number of protons in the nucleus.

A = mass number of the nuclide (atomic mass).

= number of nucleons in the nucleus (**A=Z+N**).

N =A – **Z** = number of neutrons.

For example, consider beryllium and helium : ${}^{9}_{4}\mathbf{Be}$, ${}^{4}_{2}\mathbf{He}$

Nuclear constituents

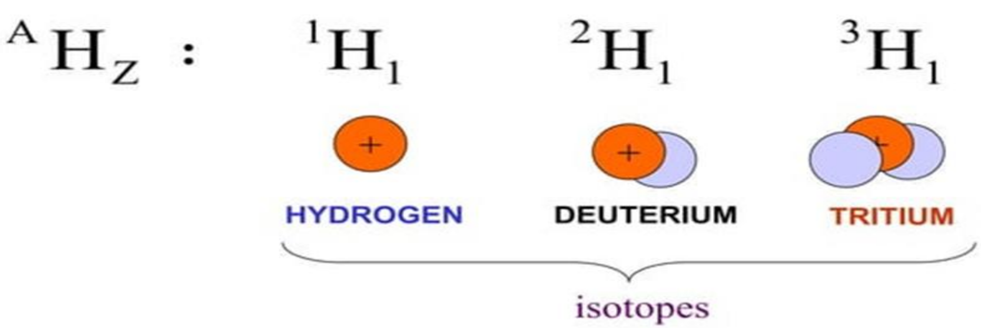
- **Nuclide**: A specific nuclear species , with given proton number Z and neutron number N.

  The following are best described as nuclides:

$$ {}_{1}^{1}H \qquad {}_{5}^{7}B \qquad {}_{7}^{14}N $$

- **Isotopes**: Nuclides of same Z and different N and different A

$$ {}_{4}^{7}Be \qquad {}_{4}^{8}Be \qquad {}_{4}^{9}Be \qquad {}_{4}^{10}Be $$



Nuclear constituents

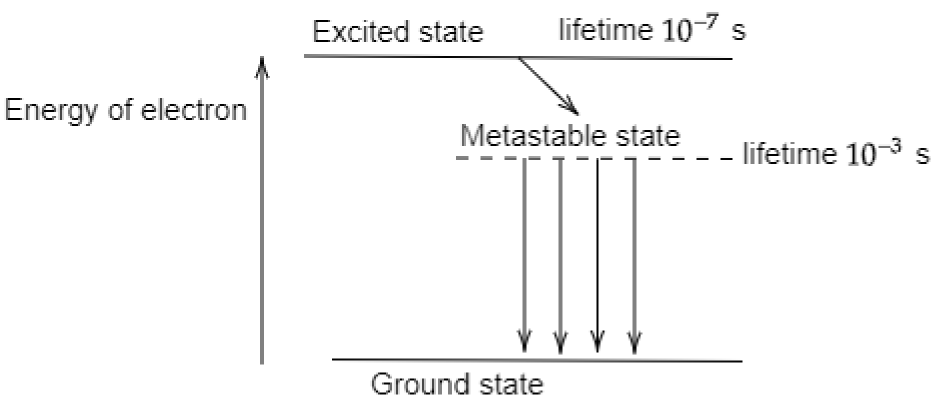
- Isotones: Nuclides of same N and different Z.

$$^{14}_{6}C_{8} \qquad ^{15}_{7}N_{8}$$

- Isobars: Nuclide of same mass number A (A= Z + N).

$$^{7}_{3}Li \qquad ^{7}_{4}Be \qquad ^{7}_{5}B$$

- Isomer: is a metastable state of a nucleus caused by the excitation of one or more of its nucleons (protons or neutrons).



Nuclear constituents

- **Nucleons**: proton and neutron.
- **Mirror nuclei**: nuclei having the same odd A with proton and neutron number interchanged.

$$ {}^{23}_{12}Mg_{11} \qquad {}^{23}_{11}Na_{12} $$

- **Positron:** Positively charged electron of mass(m_e).
- **Photon:** Quantum of electromagnetic radiation

  Example X-ray , γ-ray

Nuclear Mass

Early chemical methods of mass comparison had already brought out the following approximate relation;

$$M \approx \text{integer} \times M_H$$

Where

M=mass of a specific atom.

M_H = mass of hydrogen atom.

The integer is now called mass number will be denoted by the symbol A which is equal to Z plus N. by using the (neutron- proton) hypothesis we expect that the mass of atom to be:

$$M \approx Z\,M_H + N\,M_n$$

Common atomic masses:

Proton: 1.007276 u

Neutron: 1.008665 u

Electron: 0.00055 u

Hydrogen: 1.007825 u

The Atomic Mass Unit (a.m.u)

Because the mass of an atom is so much less than 1 Kg ,a mass unit more appropriate to measuring the mass of atoms has been defined independent of the SI kilogram mass standard. The atomic mass unit(abbreviated as amu, or just u) is defined to be $\frac{1}{12}$ the mass of a neutral ground-state atom of ^{12}C. Equivalently, the mass of Na ^{12}C atoms (Avogadro's number =1 mole)is 0.012Kg. Thus,

1 amu equals$(\frac{1}{12})(0.012Kg/Na)=1.6605387\times10^{-27}$ Kg

1amu=931.5 MeV

Mass Defect

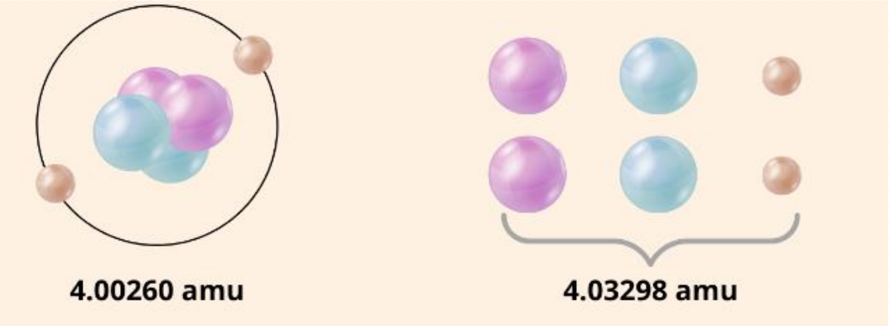
Mass defect is the difference between the actual mass of an atom and the sum of masses of its protons, neutrons, and electrons.

$$\Delta M = [(ZM_H + NMn) - A]$$

M_H=1.007825amu , M_n=1.008665 amu

Z is atomic number; N is neutron number; M is mass of atom.

Example/ Mass of an helium atom is 4.00260amu, but the mass of its components is 4.03298 amu. The difference between the values is the mass defect.



The missing mass equals the binding energy holding the atom together.

Example/ Calculate the mass defect of ${}_{4}^{9}Be$, which has a mass of 9.012182amu. The mass of a proton is 1.00727647amu and the mass of a neutron is 1.00866490amu.

Solu./

$$\Delta M = [(ZM_H + NMn) - A]$$

$$\Delta M = [(4\times1.00727647)+(5\times1.00866490)]- (9.012182)$$

$$=[(4.02910588+5.0433245) - (9.012182)]$$

$$=9.07243038 - 9.012182$$

$$\Delta M = 0.06024838 \text{ amu}$$

Properties of the Nucleus

Nuclear Size ,Density

The shape of the nucleus is taken spherical, because for a given volume this shape possesses the least surface area.

The nuclear density remains approximately constant over most of the nuclear volume. This means that the nuclear volume is proportional to the number of nucleons i.e. mass number A.

Hence radius of nucleus $R \propto A^{1/3}$

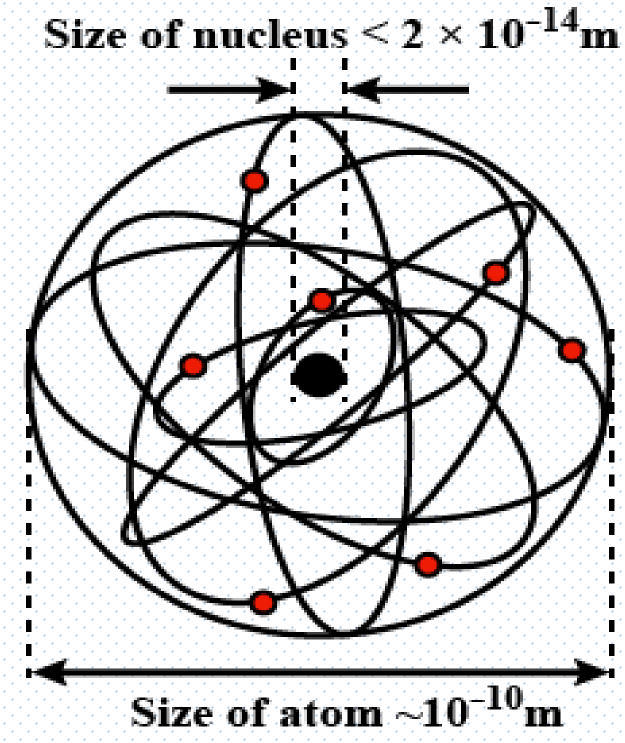
$$R = R_o A^{1/3} \quad \text{------------} \quad (1)$$

Nuclear Size ,Density

Where R_o is called the radius constant and the values;

$$R_o = \begin{cases} 1.4\ F & \text{for nuclear particle scattering on nuclei.} \\ 1.2\ F & \text{for electron scattering on nuclei.} \end{cases}$$

1Fermi=10^{-15} meter



Nuclear Size ,Density

Since the volume of a sphere is ($V = \frac{4}{3}\pi R^3$), we calculate from eq.(1)that the nuclear volume is:

$$\boldsymbol{V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi r_o^3 A}$$

$$\mathbf{V{=}1.12{\times}A = 10^{-45}A} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

That is, the volume of a nucleus is proportional to the number of nucleons (A) , Another conclusion is that nuclear matter has a constant density, this may be seen as follow the mass of nucleus of mass number (A) is approximately

$$M{=}1.66\times 10^{-27}A \quad (Kg)$$

Nuclear Size ,Density

Therefor the average density

$$\boldsymbol{\rho = \frac{M}{V} = \frac{1.66\times10^{-27}A \quad (Kg)}{1.12\times10^{-45}\ A \quad (m^3)}}$$

$$\boldsymbol{\rho = 1.49\times 10^{18}\ \ {}^{Kg}/_{m^3}} \quad \ldots\ldots\ldots\ldots\ldots(3)$$

Which is independent of (A)

H.W.

Q1/Determine the atomic mass and the mass excess of ($^{27}_{13}Al$)?.

Q2/Calculate the mass defect for Calculate the mass defect for $_3{}^7$Li . The mass of $_3{}^7$Li is 7.016003 amu.

Q3/ Determine the radii of a ^{16}O and a ^{208}Pb nucleus.

Q4/ If the radius of a nucleus is given by R=Ro $A^{1/3}$ with Ro =1.2F, what is the density of the nuclear matter (a) in g/cm3 , (b) in nucleons/F^3 .

Q5/ Determine the approximate density of a nucleus , if the nucleus is treated as a uniform from sphere .

If you know that the mass of proton (MP= 1.007825 a.m.u) and the mass of neutron (Mn= 1.008665 a.m.u)