NUCLEAR PHYSICS: (Father of nuclear Physics: Ernest Rutherford): The branch of Physics dealing with the study of atomic nucleus is called Nuclear Physics .It includes the study of properties of nucleus, nuclear phenomena, interaction of nuclei, etc. It is divided into 1) Particle Physics & 2) High energy Physics.

Nucleus: Discovered by Ernest Rutherford (New Zealand) & his co-worker Geiger & Marsden in 1911 from alpha particle scattering experiment.

Atomic number (Z): The number of protons in the nucleus of an atom is called atomic number. Number of electrons, number of protons and atomic number of an atom are always equal.

Mass number (or Atomic mass(A)): The total number of protons and neutrons present inside the nucleus of an atom is called mass number.

CONSTITUENTS OF NUCLEUS:

a) All the atomic nuclei are made up of elementary particles called protons & neutrons (except $_1H^1$, no neutron)
b) Proton is positively charged particles whose charge $e=1.6x10^{-19}C$ & discovered by Ernest Rutherford in 1919. It is a stable particles
c) Neutron is chargeless particle having rest mass $1.6748x10^{-27}Kg$ .It is unstable in Free State. It is discovered by James Chadwick in 1932.
d) Atom consists of equal number of protons & electrons. So, it is called electrically neutral.
e) A nucleus is positively charged because it contains proton which has positively charged(neutron - chargeless)
f) The nucleus consists of protons & neutrons, collectively called **Nucleons**
g) The Species of nucleus is known as nuclide.
h) A= Atomic mass or mass number, Z= Atomic number , N= number of neutron
   $N=A-Z$

GENERAL PROPERTIES OF NUCLEUS:

a) Nuclear size: The size of nucleus is very small. According to Rutherford, the size of nucleus (radius) is of order 10^{-14} m to 10^{-15} m while that of an atom is about 10^{-10}m . The empirical formula for the nuclear radius is given as $\mathbf{R=r_0(A)^{1/3}}$ where A is atomic mass & radius constant r_0=1.2 fm =1.2×10^{-15}m (experimentally determined constant)

b) Nuclear charge: A nucleus contains protons & neutrons .Protons is positively charged but neutrons are chargeless. So the nuclear charge is positive which is due to the charge carried by protons present in nucleus.

Nuclear charge (q) = +Ze where $e=1.6\times10^{-19}C$ & Z= atomic number =number of protons.

c) Nuclear mass: It is the sum of masses of protons & neutrons present in a nucleus.

Nuclear mass $(M_N)=Zm_p+Nm_n$ where m_n= mass of neutron m_p=mass of proton

M_N=mass of nucleus or nucleon

d) Nuclear density: The mass per unit volume of a nucleus is called nuclear density.

$$\rho = \frac{\textit{nuclear mass}}{\textit{nuclear volume}} = \frac{AM_N}{\frac{4}{3}\pi R^3} = \frac{3AM_N}{4\pi R^3} = \frac{3AM_N}{(4\pi\, r_0\, A^{1l3})^3} = \frac{3M_N}{4\pi r_0{}^3}$$

where $M_N= 1.67\times10^{-27}Kg$ and $r_0=1.2\times10^{-15}m$

Putting values we get, $\boldsymbol{\rho= 2.3\times10^{17}Kg/m^3}$ **.**

This shows that density of nucleus is independent of mass number (A) and its value is very high. So, all nuclei have approx. same density.

The nuclear density is not uniform throughout the nucleus. It has maximum value at the centre and decreases gradually as we move away from the centre of the nucleus.

Types of Nucleus: Nuclei is classified on the basis of number of protons, neutrons & radioactive character:

a) Isotopes: The nuclei having same atomic number but different mass number are called Isotopes.eg $_1H^1$, $_1H^2$, $_1H^3$

b) Isobars: The nuclei having same mass number but different atomic number are called Isobars. eg $_6C^{14}$ & $_7N^{14}$

c) Isotones: The nuclei having same number of neutron but different mass number & atomic number are called Isotones. eg $_3Li^7$ & $_4Be^8$

d) Mirror nuclei: The nuclei having same mass number but proton & neutron number interchanged are called mirror nuclei. eg $_4Be^7$(Z=4 , N=3) & $_3Li^7$(Z=3, N=4)

e) Isomers: The nuclei having same atomic number & mass number but differ in their radioactive characters are called Isomer. These nuclei are distinguish by their life time.

Einstein's mass-energy relation: In 1905, Einstein explained the interrelationship between mass & energy in his **special theory of relativity**. According to this theory, mass & energy are interchangeable i.e. mass can be converted into energy & vice-versa.

According to Einstein, the energy equivalent to a mass(Δm) is, $\mathbf{E=\Delta mc^2}$,

where $c= 3\times10^8 m/s$, is speed of light.

This equation represents **Einstein's mass-energy relation**. This relation explains the unification law of conservation of mass & law of conservation of energy into a single law called **law of mass-energy conservation**. So, this relation is also known as **mass-energy equivalence**.

According to this relation, 1Kg of mass of any material is equivalent to 9x 10^{16}J of energy which is equal to 2.5x10^{10}KWH (i.e. kilowatt-hour).

The mass of a body is not constant quantity. It varies with the speed of a body.

If we give energy (E) to the matter then its mass will increase. The increase in mass (Δm) is given by $\Delta \boldsymbol{m} = \frac{E}{c^2}$ **where mass is expressed in $\frac{MeV}{C^2}$**

Einstein's mass energy relation E=mc^2 does not tell us that the mass travels with the speed of light(c). Here c^2 is a conversion factor which is used to convert mass into energy & vice-versa.

Verification of E=mc^2 :
According to Newton's second law of motion, force acting on a body is defined as the rate of change of momentum.
i.e. F= $\frac{\mathrm{dp}}{\mathrm{dt}} = \frac{\mathrm{d(mv)}}{\mathrm{dt}} = \frac{\mathrm{mdv}}{\mathrm{dt}} + \frac{\mathrm{vdm}}{\mathrm{dt}}$ ....(1)
If this force F displaces the body ny a distance dx, its energy increases by,
dK = F dx = $\{\frac{\mathrm{mdv}}{\mathrm{dt}} + \frac{\mathrm{vdm}}{\mathrm{dt}}\}$dx = $\frac{\mathrm{mdv}}{\mathrm{dt}}$ dx+ $\frac{\mathrm{vdm}}{\mathrm{dt}}$ dx =m dv $\frac{\mathrm{dx}}{\mathrm{dt}}$ +v dm $\frac{\mathrm{dx}}{\mathrm{dt}}$ = m v dv + v^2 dm
∴ dK = mv dv + v^2dm, ...(2)
According to Einstein's relation of relativistic mass or Mass -velocity relation:

m = $\frac{\mathrm{m_0}}{\sqrt{\mathbf{1}-\frac{v^2}{c^2}}}$ ......(3)
squaring and manipulating (3): we get
$m^2c^2 - m^2v^2 = m_0{}^2c^2$ ....(4)
Again, differentiating (4)(with m_0 and c are constant): then we get
c^2 2m dm – m^2 2v dv – v^2 2m dm = 0
or, c^2 dm = mv dv + v^2 dm ....(5)
From (2) and (5): dK = c^2 dm ....(6)
If particle is accelerated from rest to a velocity v, let its mass m_0 increases to m.
Now, integrating (6); $\int_0^{\mathrm{K}} \mathrm{dK} = c^2 \int_{\mathrm{m_0}}^{\mathrm{m}} \mathrm{dm}$
∴ K = c^2 (m – m_0)
or, K + m_0c^2 = mc^2 ....(7)
Here, m_0c^2 is the energy associated with the rest mass of the body and K is the kinetic energy. Thus, the total energy of the body is given by E=mc^2 ....(8)
This is Einstein's mass- energy equivalence relation. Hence, verified

Significance of Einstein's mass-energy equivalence:

a) It gives a relationship between mass & energy. Thus, it shows that mass & energy can be converted into each other.

b) It forms the basis of understanding nuclear reactions like Fission & Fusion.

c) Mass -velocity relation: $\mathbf{m}=\frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$.

d) The conversion of mass into energy can be seen in many devices like Atom Bomb, hydrogen Bomb etc but yet the Scientist has not devised a machine that can convert energy into mass.

Note: The energy equivalent of mass of an electron, proton & neutron are respectively given by,

m_e= 0.511MeV **m_p = 938.28 MeV** **m_n=939.57 MeV**

ONE ELECTRON VOLT (1eV): It is defined as the kinetic energy gained by a particle with charge equal to that of an electron or a proton when accelerated through a potential difference of 1 volt. Thus, by work-energy , we have 1eV= charge X potential difference = (1e)X (1 Volt) = $1.6\text{x}\ 10^{-19}$ X(1Volt) =$1.6\text{x}10^{-19}$J

So, 1eV= $1.6\text{x}10^{-19}$J

Also, 1MeV= $1.6\text{x}10^{-13}$J

ATOMIC MASS UNIT (amu or u):

One atomic mass unit (1 amu) is defined as the **($\frac{1}{12}$)th of mass of one $_6C^{12}$** atom. As we know,

12 gram of $_6C^{12}$ contains $6.023\text{x}10^{23}$

Now, mass of $6.023\text{x}10^{23}$ atoms of $_6C^{12}$ = 12 gram

So, mass of 1 atom of **$_6C^{12}$ =$\frac{12}{6.023\text{x}10^{23}}$ gram**

By definition, 1amu =$\frac{1}{12}$ [$\frac{12}{6.023\text{x}10^{23}}$ **] gram =$1.66\text{x}10^{-24}$ Kg**

Hence, 1 amu = $1.66\text{x}10^{-27}$ Kg

RELATION BETWEEN amu & MeV:

Since, 1 amu = $1.66\text{x}10^{-27}$ Kg

We know from Einstein's mass-energy relation, the equivalent energy of this mass is $E=mc^2 = (1.66\text{x}10^{-27})\text{x}(3\text{x}10^8)^2 = 1.494\text{x}10^{-10}$J

But, 1eV= 1.6 $\text{x}10^{-19}$J

Therefore, **Energy equivalence of 1 amu = $\frac{1.494\text{x}10^{-10}}{1.6x10^{-19}}$ J = 931MeV**

MASS DEFECT (Δm): The difference between **the sum of the masses of constituent Nucleon** & **mass of a nucleus** is called the **Mass defect**.

The total mass of all the constituent Nucleon is always greater than the mass of the nucleus.

Mass defect = sum of masses of the constituent nucleon - Rest mass of nucleus

$\Delta\mathbf{m}$ **=(Zm_p+Nm_n) - M**

$\Delta\mathbf{m}$ **=[Zm_p+(A-Z)m_n]- M**

where, Z = atomic number m_p = mass of proton m_n = mass of neutron **M= rest mass of nucleus**

PACKING FRACTION (PF): The mass defect per nucleon is called Packing Fraction. It is the measure of comparative stability of an atom.

Packing fraction (PF) = $\frac{\textbf{mass defect}(\Delta\mathbf{m})}{\textbf{mass number}(\mathbf{A})}$

a) If PF >0 then the nucleus is not stable.

b) If PF <0 then nucleus is more stable

BINDING ENERGY or NUCLEAR BINDING ENERGY: The Binding energy of a nucleus is defined as the minimum energy required to separate the nucleon from the nucleus for apart to form stable nucleus.

It is also defined as the minimum energy required to bind the nucleons to form a stable nucleus. It is equivalent to mass defect. Thus mass defect is a measure of the Binding energy of the nucleus.

$$\Delta\mathbf{m} = (\mathbf{Zmp} + \mathbf{Nmn}) - \mathbf{M}\,\Delta\text{.................}\mathbf{(1)}$$

If $\Delta\mathbf{m}$ **is in Kg then Binding energy of nucleus is given by**

E_B**=**$(\Delta\mathbf{m}$ **)** c^2

E_B**=** $[(\mathbf{Zm_p} + \mathbf{Nm_n}) - \mathbf{M}\ ]\,c^2$ **....................(2)**

If Δm **is in amu or u , then Binding energy of nucleus is given by**

E_B**=**$(\Delta\mathbf{m}$ **) X 931 Mev ....(3)**

a) if $E_B > 0$ then the nucleus is stable & external energy must be supplied to disrupt into its constituent.

b) if $E_B < 0$ then the nucleus is not stable & it will disintegrate by itself.

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Mass defect = sum of masses of the constituent nucleon **-** Rest mass of nucleus

$\Delta\mathbf{m}$ **=(Zm_p+Nm_n) - M**

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$$\Delta m = (\mathrm{Zm_p} + \mathrm{Nm_n}) - \mathrm{M} \text{ ....(1)}$$

If $\Delta \mathrm{m}$ **is in Kg then** Binding energy of nucleus is given by

$E_B = (\Delta \mathrm{m}) c^2$

$E_B = [(\mathrm{Zm_p} + \mathrm{Nm_n}) - \mathrm{M}] c^2$ .... (2)

If $\Delta \mathrm{m}$ **is in amu or u ,** then Binding energy of nucleus is given by

$E_B = (\Delta \mathrm{m})$ X 931 Mev .... (3)

a) If $E_B > 0$ then the nucleus is stable & external energy must be supplied to disrupt into its constituent.

b) If $E_B < 0$ then the nucleus is not stable & it will disintegrate by itself

BINDING ENERGY PER NUCLEON & BINDING ENERGY CURVE:

a) BINDING ENERGY PER NUCLEON: It is also called average Binding Energy or Specific Binding energy. The Binding energy per Nucleon of a nucleus is called Binding energy per Nucleon. **B.E=** $\frac{E_B}{A} = \frac{[(\mathrm{Zm_p}+\mathrm{Nm_n}) - \mathrm{M}]\, c2}{A}$ ....(4) : If mass defect is in Kg

B.E= $\frac{E_B}{A} = \frac{\Delta m}{A}$ **x 931 MeV............(5): i**f mass defect is in amu or u.

- It explains the stability of the nucleus
- The greater the value of Binding energy per nucleon , the more stable is the nucleus & vice versa
- It is the average Binding energy of a nucleus.

b) BINDING ENERGY CURVE: The graph between Binding energy per nucleon & mass number of different nuclei is known as Binding energy curve. The Binding energy curve is shown in **fig 1.**

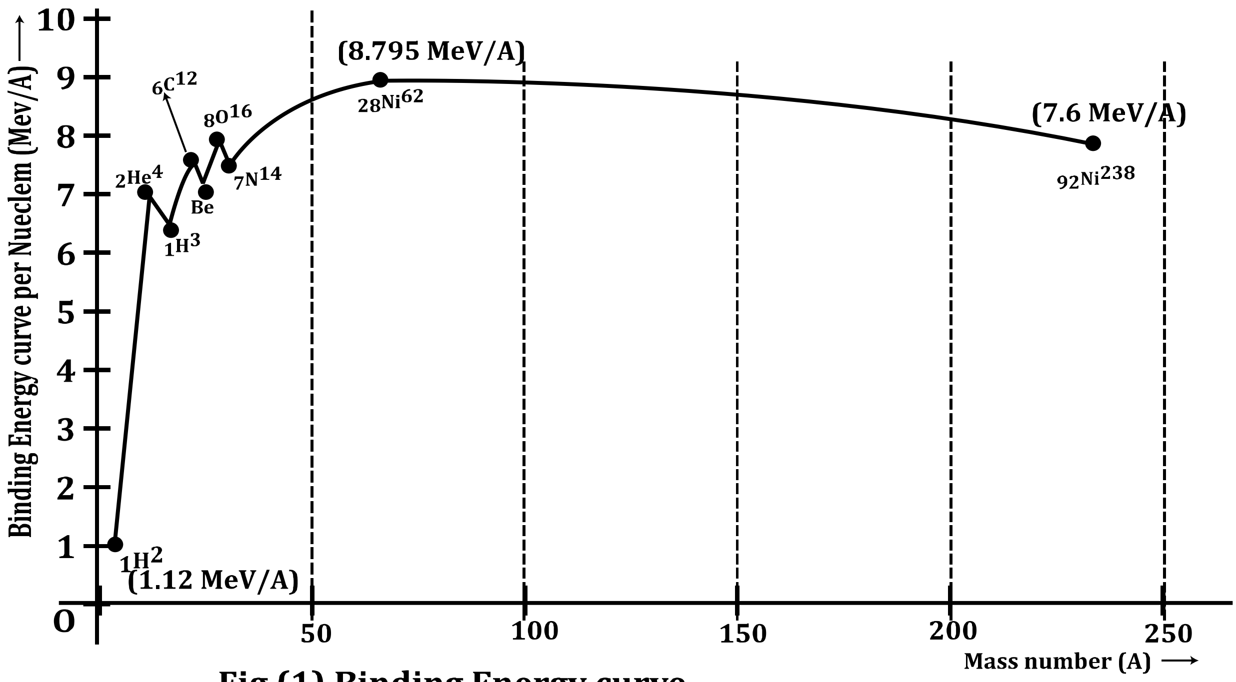


Fig (1) Binding Energy curve

Conclusions drawn from the curve:

- The curve reaches a peak of about 8.795MeV/nucleon at A=62, (Nickel). It is the measurement of stability of a nucleus
- B.E. per nucleon og light nuclei ($_1H^2$) as well as heavy nuclei($_{92}U^{238}$) is small. It shows that they are relatively less stable.
- The nuclei in the middle range (about A=50 to 80) have highest B.E. per nucleon , which shows that they are most stable.
- The peak in the graph indicates that the nuclei $_2He^4$, $_6C^{12}$, $_8O^{16}$ etc are relatively more stable than the other neighboring nuclei.
- $_{28}Ni^{62}$ has largest B.E. per nucleon (8.795 MeV/A) of all nuclides , followed by $_{26}Fe^{58}$ & $_{26}Fe^{56}$ (8.792 MeV/A & 8.790 MeV/A respectively) & $_1H^2$ has lowest B.E. per nucleon (1.12MeV/A) of all nuclides.
- Nearly all stable nuclides from the lightest to the most massive B.E per nucleon in the range of 7 to 9 MeV/nucleon.
- If a heavy nucleus is split into two medium sized nuclei (Nuclear fission **), each of the new nuclei will have more B.E per nucleon than the original nucleus. for instance, if** $_{92}U^{238}$ is splitted , B.E per nucleon increases from 7.6 MeV from 8.4 MeV.
- If two light nuclei combines to give a single heavier nucleus (Nuclear fusion) , then the newly formed nuclei have **more B.E per nucleon than the original nucleus.**

NUCLEAR FORCE:

- The nuclear force is a force that acts between the protons & neutrons of an atom.
- It is the force that binds the neutrons & protons in a nucleus together.
- The nuclear forces are the strongest force known to Physics.
- They are short range forces. They only act in the range of 10^{-15}m.

- They are non conservative force (energy released is not recovered) & charge independent forces.
- It is 100 times that of electrostatic force and 1038 times that of gravitational force.

NUCLEAR FISSION:

The phenomenon in which a heavy nucleus splits up into two fragments of nearly comparable masses & a large amount of energy is released is called Nuclear Fission. The phenomenon was discovered by two German scientist s Fritz Stresemann & Otto Hahn in 1939.

When a Uranium nucleus 92U235 is bombarded by slow neutron 0n1 then it splits into 56Ba141 & 36Kr92 along with three neutrons & huge amount of energy is released.

$_{92}U^{235} + {_0}n^1 \rightarrow {_{56}}Ba^{141} + {_{36}}Kr^{92} + 3{_0}n^1 + Q$ where Q is energy released in the process is about 200MeV.

Here, the total initial mass of $_{92}U^{235}$ & $_0n^1$ is greater than the total final mass of $_{56}Ba^{141}$, $_{36}Kr^{92}$ & $3{_0}n^1$. The decrease in mass is converted into fission energy Q according to mass - energy relation ($E=mc^2$).

ENERGY RELEASED IN FISSION:

Mass of neutron, $_0n^1$ = 1.008665 u

Mass of Uranium, $_{92}U^{235}$ = 235.045733 u

Mass of Barium, $_{56}Ba^{141}$ = 140.917704 u

Mass of krypton, $_{36}Kr^{92}$ = 91.8854 u

Mass of reactant = 1.008665 +235.045733 = 236.054398 u

Mass of product = 140.917704 + 91.8854 + 3x 1.008665 = 235.829095 u

Difference in mass(Δm) = Mass of reactant - Mass of product

=236.054398 u - 235.829095 u

=0.225303 u

Hence, energy released in a fission E= Δm x 931 MeV

= 0.225303 x 931 MeV

= 209.76 MeV

≈ 200 MeV

Again B.E. per nucleon = $\frac{E}{A}$ = $\frac{200MeV}{235}$ = 0.8 MeV

NOTE: The energy released by 1kg of $_{92}U^{235}$ is about 8.2 x 10^{13} J or 2.27 x 10^7 Kwh, which is equivalent to energy liberated in an explosion of 3000 tons of coal.

Now , one mole of $_{92}U^{235}$ has mass 235 gram & contains 6.023 x 10^{23} atoms.

i.e. 235 gm of $_{92}U^{235}$ contains 6.023 x 10^{23} atoms

so, 1 gm of $_{92}U^{235}$ contains $\frac{6.023 \text{ x } 10^{23}}{235}$ atoms

∴1000 gm of $_{92}U^{235}$ contains $\frac{6.023 \text{ x } 10^{23}}{235}$ x 1000 atoms = N(say)

Hence , fission of 1kg of $_{92}U^{235}$, the energy releases is

$$E = N x\ Q = \frac{6.023 \times 10^{23}}{235} \times 1000 \text{ a} \times 200 \text{ MeV} = 8.2 \times 10^{13} \text{ J} = 2.27 \times 10^{7} \text{ Kwh}$$

This is equal to energy released by burning three thousand tons of coal.

NUCLEAR FUSION:

The phenomenon in which two lighter nuclei are combined together to form a heavier nucleus & a large amount of energy is released is called Nuclear Fusion. It takes place at very high pressure & temperature (about 10^7K). Therefore, the fusion reaction is also known as Thermonuclear Reaction.

When two Deuterium **nuclei** $_1\mathbf{H}^2$ are fused together to form a helium nucleus $_2\mathbf{He}^4$

i.e. $_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + Q$,where Q is energy released in the process is about 24MeV

Here, the total initial masses of two Deuterium is greater than the total final mass of Helium nucleus. The decrease in mass is converted into fusion energy Q according to mass - energy relation ($E=mc^2$).

ENERGY RELEASED IN Fusion:

Mass of Deuterium $_1\mathbf{H}^2$ = 2.014102 u

Mass of Helium $_2\mathbf{He}^4$ =4.002604 u

Mass of reactant = 2 X 2.014102 u = 4.028204 u

Mass of product = 4.002604 u

Difference in mass(Δm) = Mass of reactant - Mass of product

=4.028204 u - 4.002604 u

=0.0256 u

Hence, energy released in a fission E= Δm x 931 MeV

= 0.0256 x 931 MeV

= 23.83 MeV

≈ 24 MeV

Again B.E. per nucleon = $\frac{E}{A} = \frac{24\ MeV}{4}$ = 6 MeV

This shows that huge amount of energy is released during nuclear fusion.

NOTE: The energy released by 1kg of $_2He^4$ is about 5.8×10^{14}J or 1.6×10^8 Kwh, which is equivalent to millions tons of coal.

Now , one mole of pairs $_1\mathbf{H}^2$ has mass(2 X 2)gm contains 6.023×10^{23} atoms.

i.e. 4 gm of $_1H^2$ pairs contains 6.023×10^{23} atoms

or, 1 gm of $_1H^2$ pairs contains $\frac{6.023 \times 10^{23}}{4}$ atoms

∴1000 gm of $_1H^2$ pairs contains $\frac{6.023 \times 10^{23}}{4} \times 1000$ atoms = N(say)

Hence , fusion of 1kg of $_1H^2$ pairs , the energy releases is

$E = N \times Q = \frac{6.023 \times 10^{23}}{4} \times 1000 \text{ a} \times 24MeV = 5.8 \times 10^{14} J = 1.6 \times 10^{8}$ KWh

This is equal to energy released by burning million tons of coal.

Q-Value of a nuclear reaction: It indicates that the energy releases or absorbs during the nuclear reaction. It is based on Einstein mass energy relation ($E=mc^2$). The energy change occurring in a nuclear reaction is termed as Q- value of the nuclear reaction.

- ✓ If Q-value > 0 then energy is released & reaction I called Exothermic or Exoergic reaction.
- ✓ If Q- value <0 then energy is absorbed & reaction is called Endothermic or Endoergic reaction.

NOTE: A neutron having energy less than 10 eV is called slow neutron.
[1KWh= 3.6×10^6J]

MULTIPLICATION FACTOR (K): The ratio of number of secondary neutrons produced to the number of initial neutrons is called multiplication factor (K).

I.e. $K = \frac{\text{number of neutron in any generation}}{\text{number of neutron in previous generation}}$

If K>1, the chain reaction is dying down or subcritical.
IF K<1, the chain reaction is steady or critical.
If K=1, the chain reaction is building or supercritical.

CRITICAL SIZE & CRITICAL MASS: The minimum size of fissionable material to sustain chain reaction is called critical size. The mass corresponding to critical size is called critical mass. If the size of fissionable material is less than critical size then a chain reaction is not possible.

CHAIN REACTION: The fission reaction which continues until all the fissionable material is disintegrated is called chain reaction. It is self propagating reaction. e.g. When ${}_{92}U^{235}$ is bombarded with slow neutron (${}_{0}n^{1}$), three additional neutrons are released with emission of about 200MeV energy. These three neutrons strike three other Uranium nuclei, producing 9 neutrons & excess of energy. This process is happening till the whole fissionable material is disintegrated & huge amount of energy is released.

TYPES OF CHAIN REACTION:

a) UNCONTROLLED CHAIN REACTION: It is a chain reaction in which the energy produced cannot be controlled. In this reaction, the number of neutron goes on increasing geometrically & such a reaction proceeds very quickly with the releasing of huge amount of energy. So this reaction is also called explosive chain reaction. This principle is used in Atom Bomb.

b) CONTROLLED CHAIN REACTION: It is a chain reaction in which energy produced can be controlled in a desired level. In this reaction, the moderator [like graphite, heavy water (D_2O)] is used for slowing down the fast neutrons. This Principle is used in Nuclear reaction.

DIFFERENCE BETWEEN NUCLEAR FISSION & NUCLEAR FUSION:

NUCLEAR FISSION:

a) Splitting of a heavy nucleus into light nuclei.

$_{92}U^{235} + {_0}n^1 \rightarrow {_{56}}Ba^{141} + {_{36}}Kr^{92} + 3{_0}n^1 + Q$ where Q is energy released

b) Energy released per fission of Uranium is around 200MeV

c) Energy released per nucleon is about 0.8MeV

d) Controlled fission reaction is the possible & is being used for constructive purpose in nuclear reactor.

e) Uncontrolled fission reaction is principle of atom bomb

f) No restriction of temperature

g) sources for nuclear fission are limited

h) A minimum mass known as critical mass is required to start fission

i) It is induced by neutrons

j) Fuel is either in solid or in liquid state

k) It is a single stage reaction & quick process

l) By products are harmful m) It produces nuclear pollution.

NUCLEAR FUSION:

a) Combination of lighter nuclei to form a heavy & stable nucleus

i.e. $_1H^2 + {_1}H^2 \rightarrow {_2}He^4 + Q$,where Q is energy released

b) Energy released per fusion is around 24MeV

c) Energy released per nucleon is 6MeV

d) Controlled fusion reaction is not discovered yet.

e) Uncontrolled fusion reaction is the principle of Hydrogen Bomb

f) About 10^7K temperature is needed to start fusion

g) Sources for nuclear fusion reaction are almost unlimited.

h) No minimum mass is required for nuclear fusion.

i) It is Induced by protons

j) Fuel is in Plasma state

k) It is multi-stage reaction

l) By products are safe m) It produces thermal pollution.

DIFFERENCE BETWEEN CHEMICAL REACTION & NUCLEAR REACTION:

Chemical reaction:

I. In this reaction , only outer most electrons take part while nuclear composition remains the same

II. It may be reversible

III. No new atoms are formed

IV. Total number of atoms should be conserved

V. It is influenced by the change in pressure & temperature

Nuclear reaction:

I. In this reaction, nucleus of an atom is involved so nuclear composition is changed.

II. It is irreversible
III. New nuclei are formed
IV. Total mass number & atomic number are conserved
V. It is not influenced by the change in pressure & temperature

Dalton's Model of an atom: John Dalton, a British school teacher, published his theory about atoms in 1808. His findings were based on experiments and the laws of chemical combination.

Postulates

1. All matter consists of indivisible particles called atoms.
2. Atoms of the same element are similar in shape and mass, but differ from the atoms of other elements.
3. Atoms cannot be created or destroyed.
4. Atoms of different elements may combine with each other in a fixed, simple, whole number ratios to form compound atoms.
5. Atoms of same element can combine in more than one ratio to form two or more compounds.
6. The atom is the smallest unit of matter that can take part in a chemical reaction.

Drawbacks of Dalton's Atomic Theory

- The indivisibility of an atom was proved wrong: an atom can be further subdivided into protons, neutrons and electrons. However an atom is the smallest particle that takes part in chemical reactions.
- According to Dalton, the atoms of same element are similar in all respects. However, atoms of some elements vary in their masses and densities. These atoms of different masses are called isotopes. For example, chlorine has two isotopes with mass numbers 35 and 37.
- Dalton also claimed that atoms of different elements are different in all respects. This has been proven wrong in certain cases: argon and calcium atoms each have an atomic mass of 40 amu. These atoms are known as isobars.
- According to Dalton, atoms of different elements combine in simple whole number ratios to form compounds. This is not observed in complex organic compounds like sugar ($C_{12}H_{22}O_{11}$).
- The theory fails to explain the existence of allotropes; it does not account for differences in properties of charcoal, graphite, diamond.

Thomson's Model of atom:

According to J.J. Thomson, the electron is a constituent of all matter. It has a negative charge of $1.602X10^{-19}$C and a mass of $9.11X10^{-31}$Kg at rest. Electrons are distributed along with positive charges in an atom in a sphere of radius 10^{-10}m like a plum pudding. Atom is electrically neutral as there are an equal number of positive and negative charges.

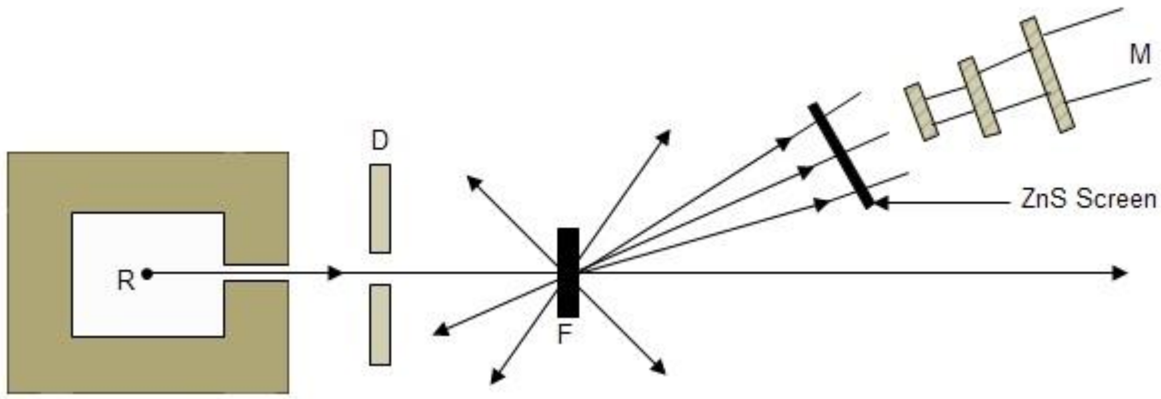
Failure of Thomson's Atomic Model:

1) It could not explain the origin of spectral series as in case of a hydrogen atom.
2) It could not explain the largest angle of scattering of α-particles from the metal foil, as observed by Rutherford.

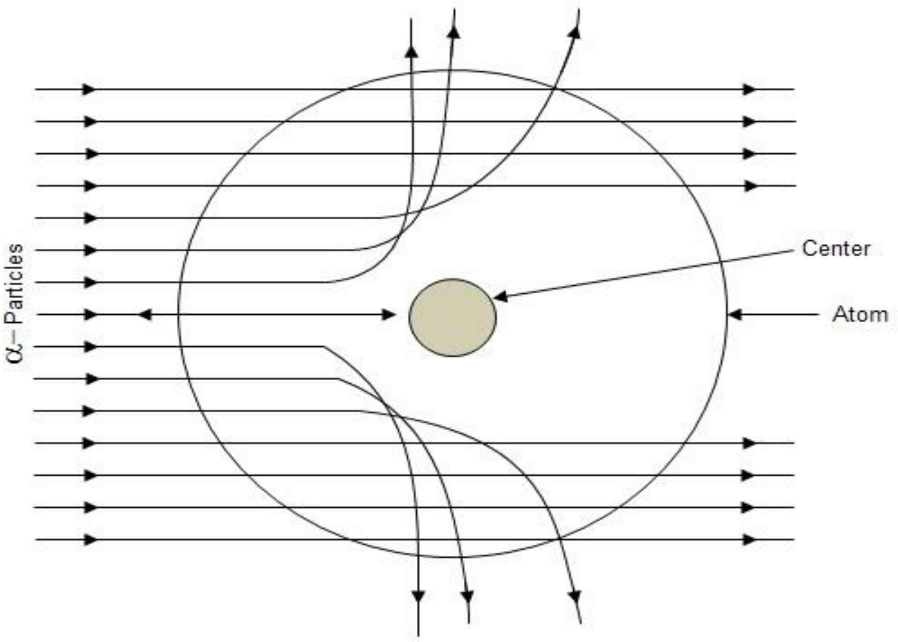
Rutherford's Alpha Scattering Experiment:

Rutherford's conducted an experiment by bombarding a thin sheet of gold with α-particles and then studied the trajectory of these particles after their interaction with the gold foil.

In this experiment, high energy streams of α-particles from a radioactive source (Polonium, R) kept inside a thick lead box. This collimated beam is then allowed to fall at a thin sheet (100 nm thickness) of gold F. While passing through the gold foil, the α-particles are scattered through different angles. The scattered α-particles are in a particular direction are allowed to strike on a screen coated with zinc sulphide. When α-particle is incident on zinc sulphide, it produces fluorescence and is detected with the help of Microscope M.



Observations of Rutherford's Alpha Scattering Experiment:



1. Most of the α-particles pass straight (without any deflection) through the gold foil, **and hence most of the space in an atom is empty.**
2. Some of the α-particles were deflected by very small angles, and **hence the positive charge in an atom is not uniformly distributed. The positive charge in an atom is concentrated in a very small volume.**
3. There were a few α-particles that were deflected by very large angles because α-particles were being repelled by a massive positive charge concentrated in a very small region of space.
4. Very few of the α-particles were deflected back, that is only a few α-particles had nearly 180° angle of deflection. So the **volume occupied by the positively charged particles in an atom is very small as compared to the total volume of an atom**.

Hence, this experiment showed that the atom is mostly empty with a tiny, dense, and positively-charged nucleus.

Rutherford Atomic Model

Based on the above observations and conclusions, Rutherford proposed the atomic structure of elements. According to the Rutherford atomic model:

1. The positively charged particles and most of the mass of an atom was concentrated at its centre in a very tiny region of the order 10^{-15}m called as a nucleus.
2. Rutherford model proposed that the negatively charged electrons surround the nucleus of an atom. He also claimed that the electrons surrounding the nucleus revolve around it with very high speed in circular paths(orbits).
3. The total positive charge of nucleus is equal to the total negative charge on electron. Therefore an atom as a overall is neutral.

4. Electrons being negatively charged and nucleus being a densely concentrated mass of positively charged particles are held together by a strong electrostatic force of attraction.

Limitations of Rutherford Atomic Model:

1) It could not explain the stability of an atom.
2) It did not say anything about the arrangement of electrons in an atom.
3) It failed to explain the line spectra of Hydrogen.

1) What is Rutherford alpha particle scattering experiment?

This is also known as Rutherford's gold foil experiment or Geiger Marsden alpha scattering experiment. This is the experiment which led Rutherford to conclude that an atom is mostly empty and understand the concept of nucleus. Its outcome discarded the Thomson model of atom

2) What were the conclusions of Rutherford's alpha particle scattering experiment?

Most of the space inside the atom is empty because most of the α-particles passed through the gold foil without getting deflected. Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space

3) What were the results of the alpha particle scattering experiment?

Conclusions and arguments: The results of this experiment were not in sync with the plum-pudding model of the atom as suggested by Thomson. Rutherford concluded that since alpha particles are positively charged, for them to be deflected back, they needed a large repelling force

4) Why did Rutherford use alpha particles in his experiment?

Rutherford wanted to check the postulates of Thompson and hence he used POSTIVILEY CHARGED ALPHA PARTICLES IN HIS SCATTERING EXPERIMENT. ... almost all of the radiations passed through the gold foil without any deviation and only a few, maybe 1 in 10,000 , suffered a scattering, which indicates that atoms are hollow

5) Why did Rutherford use gold foil?

Rutherford lacked the endurance for this work, which is why he left it to his younger colleagues. For the metal foil, they tested a variety of metals, but they preferred gold because they could make the foil very thin, as gold is very malleable

6) Why Alpha particles are deflected?

Most of the alpha particles did pass straight through the foil. The atom being mostly empty space. A small number of alpha particles were deflected by large angles (> 4°) as they passed through the foil. ... Like charges repel, so the positive alpha particles were being repelled by positive charges.

7) How did Rutherford get alpha particles?

The origin of alpha particles is the nucleus of an atom. Double-ionizing a helium atom does not produce an alpha particle. As pointed out, the source of alpha particles that was used by Rutherford and his associates was the radioactive decay of Radium, where alpha particles are produced in abundance

8) What is the most important discovery made by the alpha particle scattering experiment?

Rutherford's alpha-particle scattering experiment was responsible for the discovery of atomic nucleus. Nucleus contains most of the mass. Most of the atom has empty

9) **What did Rutherford's gold foil experiment prove?**

Thomson's plum pudding model of the atom had negatively-charged electrons embedded within a positively-charged "soup." Rutherford's gold foil experiment showed that the atom is mostly empty space with a tiny, dense, positively-charged nucleus. Based on these results, Rutherford proposed the nuclear model of the atom.

10) **What was the thickness of gold foil used in Rutherford's experiment?**

Because it is unusually ductile, gold can be made into a foil that is only 0.00004 cm thick. When this foil was bombarded with -particles, Geiger found that the scattering was small, on the order of one degree. These results were consistent with Rutherford's expectations

11) **What were two conclusions of the gold foil experiment?**

Conclusion of Rutherford's scattering experiment:

Most of the space inside the atom is empty because most of the α-particles passed through the gold foil without getting deflected. Very few particles were deflected from their path, indicating that the positive charge of the atom occupies very little space

THE END