UNIT - I
ATOMIC NUCLEUS

1) Nuclear size;

Nucleus is spherical in shape we know that volume is directly proportional to mass

Nuclear volume α mass number

(Or)

$4/3\, \pi R^3 \;\alpha\; A$

$R^3 \;\alpha\; A$

$\mathbf{R \;\alpha\; A^{1/3}}$

$\mathbf{R = R_0\, A^{1/3}}$

This expression gives radius of nucleus here $\mathbf{R_0}$ is constant

$\mathbf{R_0}$**=** 1.3×10^{-15} m

(or)

$R_0 = 1/3$ F

Where F = Fermi $= 1 \times 10^{-15}$m

Examples

Radius of carbon nucleus for carbon ${}_6C^{12}$ A= 12

$R = Ro\, A^{1/3}$

R = 1.3×10^{-15} m $(12)^{1/3}$m

2) Nuclear charge

Proton has positive charge and neutron has no charge the charge of the nucleus is given by

Charge of nucleus =+Ze

Where, Z =Atomic number

E = charge of election or proton

E= $\mathbf{1.6 \times 10^{-19}}$**C**

3) Nuclear mass:

Nuclear mass is the sum of mass of all protons and mass of all neutrons

Nuclear mass $= Zm_p + (A-Z)\, m_n$

Where, m_p –mass of one proton

m_n–mass of one neutron

$m_p = 1.66 \times 10^{-27}$ kg

$\mathbf{m_n} = 1.67 \times 10^{-27}$ kg

4) Nuclear density

Nuclear density = Nuclear mass

Nuclear volume

$$= (Zmp + (A-Z)\, m_n) / (\tfrac{4}{3}\pi R^3)$$

Here

R= $R_0\ A^{1/3}$

Nuclear density = $(A\, m_p) / (4/3\pi R_0 A)$

R = 1.3×10^{-15} m

Nuclear density = $3 \times 1.66 \times 10^{-27} / 4 \times 3.14 \times 1.3 \times 10^{-15}$

P = 2×10^{17} **kg/m³**

5) Nuclear spin:

Nuclear spin arises due to orbital angular momentum and spin angular momentum.

Spin of a proton is $\pm \frac{1}{2}\hbar$

Spin of a neutron is $\pm \frac{1}{2}\hbar$

Where $\hbar = h/2\pi$

h planck's constant

6) Nuclear magnetic moment:

It arises due to orbital magnetic moment and spin magnetic moment

Orbital magnetic moment = $\mu_l = e/2m\bar{L}$

Where e – charge of election

m – mass of election

$\bar{L} = l\hbar$ Orbital angular momentum

$\mu_l = e/2m\ l\hbar$

$\mu_l = e/2m\ l\,(h/2\pi)$

$\mu_l = eh/4\pi m\ l$

$\mu_l = \mu_B l$

Where μ_B — Bhor magneton

Similarly,spin magnetic moment = $\mu_S = e/m\ \bar{S}$

Where $\bar{S}$ spin angular momentum

7) Nuclear Quadra polemoment:

It forces used to bind the protons and neutrons in the nucleus are called the nuclear forces. There are three types of the interaction in the nucleus .There are

Proton – proton interaction

Proton – neutron interaction

Neutron – neutron interaction

Nuclear forces arises due to the above interactrion π- means (points) are the responsible for nuclear forces.

Characteristics of nuclear forces:

1) Short range:

Nuclear forces are effective, when the range is in the order of 10^{-15}m

2) Charge independent:

A proton has positive charge and neutron has no charge .Therefore nuclear forces are charge independent.

3) Spin dependent:

A proton has spin of ± ½ and neutron has spin of ± ½.Therefore nuclear forces are spin dependent.

4) Attractive forces:

Nuclear forces are attractive in nature.

5) Strong force:

Nuclear forces are the strongest forces compared to the gravitational forces and electromagnetic forces.

6) Saturation property:

Nuclear forces are saturated forces

Mass defect

Mass defect is the difference between the total mass of the protons and neutrons and the nuclear mass (m)

$$\text{Mass defect} = \Delta m = [Zm_p + (A-Z)\, m_n] - m$$

Where, Z Atomic number

M_p- mass of a proton

M_n – Nuclear mass

Binding energy:

The energy used to bind the protons and neutrons in the nucleus is called the binding energy .The binding energy is

Given by,

BE=(Δm) C^2joules

WhereΔm— Mass defect

C— velocity of light

In atonic mass unit (a.m.u)

B.E =(Δm) amu

=Δm931 MeV

Where 1 amu= 931MeV

Example ;

Binding energy of a deuterium nucleus $_1H^2$

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

Here, A = 2, Z =1,mp =1.0033 amu ,m_n= 1.0045 amu

M = 2.0055 amu

$\Delta m = [(1x1.0033) + (1x\ 1.0045)]-2.0055$

$\Delta m = 0.04$ amu

BE= Δmamu

Binding energy curve is drawn between binding energy per nucleon and mass number

Binding energy per nucleon is given by BE per nucleon = $\frac{BE}{A}$ or $\frac{B}{A}$

Where, BE or B Binding energy

A graph is drawn between binding energy per nucleon and mass number (A) ia shown

Observation:

(i) For light elements, the binding energy per nucleon (B/A) increases as the mass number increases.

(ii) For heavy elements, the binding energy per nucleon (B/A) decreases as the mass number increases.

(iii) Binding energy curve has some sharp peaks in light element side.

(iv) Each sharp peak represents the stable nucleus.

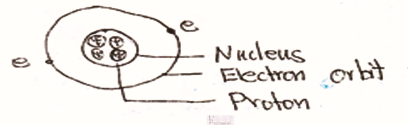
Applications:

(i) Binding energy curve is used to explain the stability of the nucleus.

(ii) it is used to explain nuclear fission and emission of α, β, gamma radiations.

Proton – electron hypothesis (proton only model):

According to proton – electron hypothesis, the nucleus consists of only proton .Hence this model is called as proton only model. The diagram for proton only model is given below.



In the above diagram, the nucleus consists of only protons. The electrons revolve in around the nucleus. The nucleus consists of A number protons.
The number charge is –Ae

Where A – Mass number

E – Charge of electron

Therefore nuclear charge is positive.

The charge of all electron is – Ze

The net charge of the atom is +Ae-ze =

Hence, the atom is not neutral.

Drawbacks:

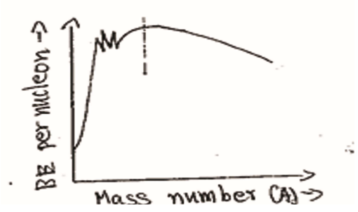
(i) This model does not explain about neutrons

(ii) Proton –electron hypothesis says that the atom not neutral.

(iii) It is a failure model.

Proton – Neutron hypothesis;

According to proton – neutron hypothesis the nucleus consists of proton and neutrons. Hence this is called as proton – neutron model. The diagram for proton – neutron model is given below.



In the above diagram, the nucleus consists of proton and neutrons. The electrons revolve around the nucleus. The nucleus charge is + Ze

Where, Z- Atomic number

e – charge of electron

Therefore nuclear charge is positive. The charge of all electron is – Ze

The net charge of the atom is Ze – Ze =0

Hence the atom is neutral.

Advantages ;

(i) This explains about the neucleons.

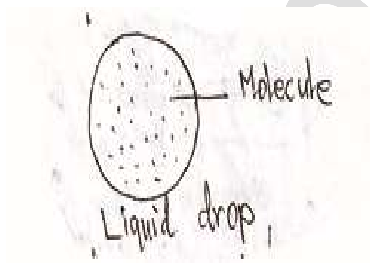
(ii) Proton – Neutron hypo thesis says that the atom is neutral.

(iii) This model is a successful model

Liquid drop model;

It was proposed by Nelis Bohr in 1936. Liquid drop model is used to explain the nuclear properties like, nuclear size, nuclear charge, nuclear density, nuclear fission, nuclear fusion, etc.

A Nucleus is similar to liquid drop. The diagram for liquid drop model is given below.

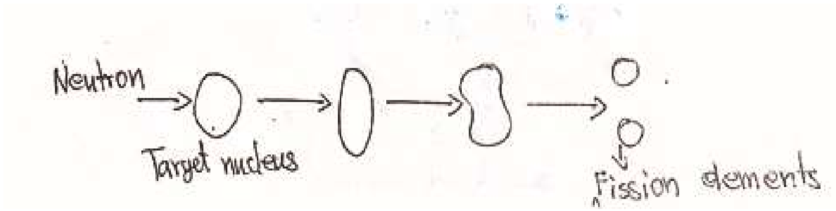


The liquid drop consists of molecules. The assumption and similarities between the liquid drop and nucleus is given below.

S.no	Liquid drop	Nucleus
1.	Spherical in shape	Spherical in shape
2.	Consists of molecules	Consists of nucleons
3.	Density is uniform	Density in uniform
4.	Surface tension	Surface energy barrier
5.	Breaking of liquid drop	Nuclear fission
6.	Condensation	Nuclear fusion
7.	Evaporation	Emission of α, β, γ , radiation
8.	Latent heat	Binding energy per nuclear

Explanation:

Based on the similarities between the liquid drop and nucleus, the nucleus properties are obtained. A large liquid drop is changed into small liquid drops. Similarly a heavy nucleus is changed into small nuclei. This is called nuclear fission. The Diagram for nuclear fission is given below.



When a liquid drop is heated, it is evaporated similarly α, β,γ particles come out from the nucleus.

(i) Liquid drop model is used to obtain nuclear properties.

(ii) Liquid model is used to explain nuclear fission and nuclear fusion.

(iii) Liquid drop model is used to derive weizsackers semi empirical mass formula.

Demerits

(i) Liquid drop model cannot explain about magic numbers.

(ii) This model cannot explain about spin and stability of the nucleus.

(iii) This model cannot explain about spin – orbit interaction and nuclear magnetic moments.

Binding Energy Formula ;

(Weiz Sackers semi empirical mass formula)

Weiz sackers semi empirical mass formula is given by

Formula

$BE = E_b = a_1A, -a2\ A^{2/3} - a_3z(z-1)/A^{1/3} - a_3\ z(z-1)^2/A^{1/3}$....

Where, A – Mass number.

Z – Atomic number.

a_1, a_2 , a_3 constants

This formula consists of s terms.

(i) The formula consists represents volume energy.

(ii) The second term represents surface energy.

(iii) The third term represents coulomb energy

(iv) The fourth term represents asymmetry energy.

(v) The fifth term represents pairing energy.

Explanation & derivation:

Volume energy;

Volume energy depends on the mass of the nucleus.

Volume energy α mass number

(or)

$E_v \alpha A$

$$E_v = a_1 A$$

Where a_1 – constants

Surface energy;

Surface energy depends on the surface of area of the nucleus.

Surface energy α surface area

Formula

$$E_S \alpha\ 4\pi R^2$$

but $R\ \alpha\ A^{1/3}$

$R = R_0\ A^{1/3}$

$$E_S \alpha\ 4\pi A^{2/3}$$

$$E_S \alpha = a_2 A^{2/3}$$

Due to surface tension surface barrier energy the surface energy is negative

$$E_S \alpha = -a_2 A^{2/3}$$

Coulomb energy ;

Coulomb energy depends on the repulsive force between the protons.

The potential energy for one pair of protons is ,

$$V = -e2/\ 4\pi\varepsilon_0 R$$

Where, e – Electronic charge

ε_0 -- Permittivity of free spaces

R – Radius of nucleus

There are (Z (Z-1)) /2 pairs of protons in the nucleus

The coulomb energy = $E_c\ \alpha - e^2/\ 4\pi\varepsilon_0 R\ [z\ (z-1)/2]$

$$E_c\ \alpha - e^2/\ 4\pi\varepsilon_0\ A^{1/3}\ [z\ (z-1)/2]$$

Or $$E_c\ \alpha = -a_3 z\ (z-1)/\ A^{1/3}$$

Asymmetry energy:

Asymmetry energy depends on the excess of neutrons in the nucleus .The excess of neutrons is given below.

We know that ,N= A-Z

Where , N – Neutron number

A – Mass number

Z – Atomic number

(or) N-Z = A-Z-Z

N-Z =A- 2Z

This given excess of neutrons = $\frac{a-2z}{A}$

Asymmetry energy = Ea α excess of neutrons X fraction of neutrons.

Formula

$$E_a \propto (A-2Z)(A-2Z)/A$$

$$E_a = -a_4 (A-2Z)^2/A$$

Pairing energy;

Pairing energy depends on proton pairs and neutrons pairs. It is found that the pairing energy is directly proportional to $\pm A^{-3/4}$

Formula

$$E_p \propto (\pm A^{-3/4})$$

Or $E_p = a_5 A^{-3/4}$

Combining the equation 1,2,3,4 and 5 we get

$$\text{Total BE} = E_b = E_v+E_s+E_c+E_a+E_p$$

$$E_b= a_1A, -a_2 A^{1/3}- a_3z(z-1)/A^{1/3}- a_3 z(z-1)^2/A^{1/3}....$$

This is the semi empirical mass formula

Application;

This formula is used to calculate the binding energy of the nucleus.

Shell Model:

It was proposed by Hanal, Mayer and other in 1937.

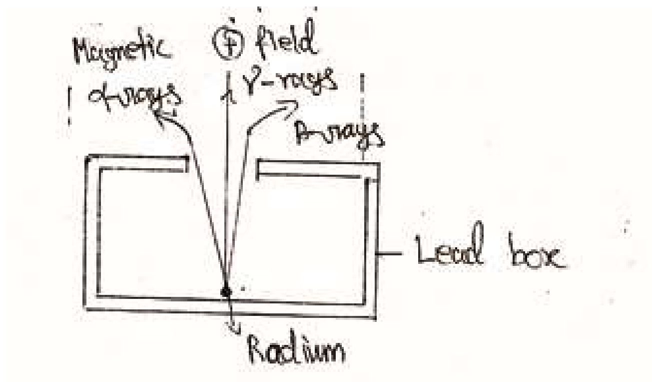
Shell model is used to explain the nuclear properties like spin, stability and nuclear moments as magic numbers. The diagram for shell model is

UNIT - II
RADIO ACTIVITY

Natural's radioactivity:

The emission ofα, β and γ rays from a heavy nucleus elements like radium is called the radioactivity. Spontaneous emission of radiations is called naturals radioactivity.

The diagram for natural radioactivity is given below diagram



In the above diagram radium is kept in the lead box α, β and γ rays are coming out from the radium. The magnetic fields is applied to separate the α, β and γ rays

Observation:

1. α - Rays have positive charge
2. β - Rays have negative charge
3. α - Rays consists of helium nuclei2
4. β - Rays consists of electrons
5. β - Rays consists of photons
6. α - Rays are electromagnetic radiations
7. β - Rays have no charge
8. α - Rays and ß rays are deflected by magnetic field

For oxygen $_8O^{16}$

Proton number z =8

Neutron number N = A – Z = 8

Oxygen is doubly magic. Therefore oxygen nucleus is most stable.

To obtain magic numbers:

The magic numbers are obtained from the following nuclear energy level diagram.

Without 2(2l+1) with spin- orbit interaction magic number

From the above diagram the magic numbers 2, 8, 2 are obtained

MERITS:
(i) The shell model is used to find the spin and stability of nucleus.
(ii) Shell model is used to find magic numbers.
(iii) It is used to find nuclear magic moment.

DEMERITS;
(I) Shell model does not explain about quadruple moment.
(ii) It cannot explain about even – even nuclei.
(iii) It cannot explain about odd – odd nuclei.

Emission of α rays:

The equation for emission of α rays is given below:

$_{92}U^{238} \text{—} {}_2He^4 + {}_{90}{}^{Th234}$

Emission of β rays

The equation for emission of β rays is given below:

$_{90}U^{234} \text{—} {}_1e^{-} + {}_{91}Pa^{234}$

Emission of gamma rays

$_{38}Sr^{97} \text{—} {}_{38}Sr^{97} + \gamma$ ray

The equation for emission of γ ray is given below

Unstable

Properties of α rays:

1) α rays have positive charge.

2) α rays consists of helium nuclei $_2He^4$

3) α rays move in a straight line.

4) α rays are deflected by magnetic and electric field.

5) α rays affect photographic plate

6) α rays cause fluorescence.

7) High ionising power.

8) Low penetrating power.

Properties of β rays.

1) β rays have negative charge.

2) β rays consists of electrons.

3) β rays move in a straight line.

4) β rays are deflected by magnetic and electric field.

5) β rays affected photographic plate.

6) β rays cause fluorescence.

7) Low ionising power.

8) Low penetrating power.

Properties of γ rays.

1) γ - rays have no charge.

2) γ - rays move in a straight line.

3) γ - rays consists of photons.

4) γ - rays are not deflected by magnetic and electric field.

5) γ - rays affect photographic plate.

6) γ – rays cause fluorescence.

7) Very low ionising power.

8) High penetrating power.

9) γ – rays are electromagnetic radiation

10) γ – rays have high energy.

Series:

The emission of α rays, β and γ,rays from a heavy nucleus like radium is called radioactivity. There are four types of radioactivity series.

1) Thorium series, A =4n

2) Neptunium series, A =4rn +1

3) Uranium series, A =4r +2

4) Actinium series, A = 4n+3

Where, A – mass number, n – variable

Thorium series:

This series starts from thorium and ends at lead. The parent nucleus is thorium.

For daughter nuclei, mass number is divided by 4.

Neptunium series:

This series starts from neptunium and ends lead. The parent nuclei are neptunium. For daughter nuclei, mass number is divided by $\frac{A-1}{4}$

Uranium series:

This series starts from uranium and ends at lead. The parent nucleus is uranium. For daughter nucleus mass number is divided by $\frac{A-1}{2}$

Law of disintegration

(Exponential law)

This is also called as law of decay. The emission of α rays, β rays, γ rays from a heavy nucleus (element) like radium is called radioactivity.

The rate of disintegration = $\frac{-dn}{dt} \alpha N$

Where N – number of atoms (or) nuclei in the sample

dn – number of atoms to decay in the time

Negative sign indicates that atoms are reduced. The above equation can be written as,

$$\frac{-dn}{dt} = \alpha N$$

Where λ disintegration constant

$\frac{dN}{dt}$ = - Ndt

Integrating, $\log_e N = -\lambda t + c$

Where, C integrating constant

$\log_e No = - 0 + C$

$\log_e No = C$

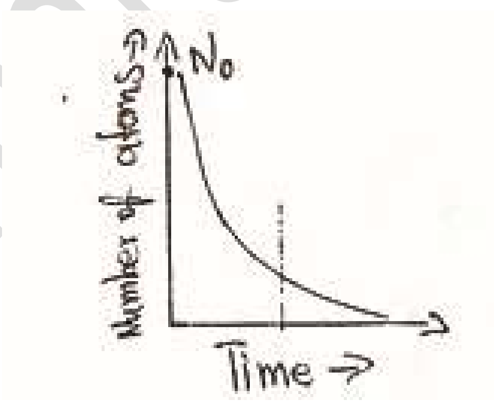
$\log_e N = -\lambda t + \log_e No$

$\log_e N - \log_e No = -\lambda t$

$\log_e \frac{N}{No} = -\lambda t$

$$N = N_o e^{-\lambda t}$$

This is called as the law of disintegration. The diagram for law of disintegration is



In the above graph, No is the original numerical atoms at t= 0

Half-life period (T)

Half-life period is defined as the times half the number of atoms to decay

Expression for half-life period

We know that

$N = \frac{No}{2}$

Λ --- Decay constant, t-- time

At half life $N = \frac{No}{2}$ t=T

$\frac{No}{2} = N_o e^{-\lambda t}$

$½ = e^{-\lambda t}$

$2 = e^{\lambda t}$

Taking $\log_e$

$T = \log e \, ^2/\lambda$

$$T = 0.693/\lambda$$

This is the expression for half-life period mean life period (T)

Mean life period = $\frac{\text{Total time}}{\text{Total number of atoms}}$

We get Mean life τ = 1/ λ

λ -- decay constant

Activity

Activity is defined as number of disintegrations per second.

Activity = $\frac{dN}{dt}$ α N

$\frac{dN}{dt} = \lambda N$

Where λ decay constant.

Radio carbon dating:

This model is used to find the age of geological samples Ratio carbon is γ. It is an isotope. It is a radioactive isotope. It emits α,β and γ rays. The half life period of $_6c^{14}$ is 5600 years.

C^{14} is produced in the atmosphere by fast neutrons bombarding on the ^{14}n nitrogen atoms in fast atmosphere.

$_0n^1 + {_7N^{14}}$------ $_7N^{15*}$--- $_6C^{14} + {_1P^1}$

C^{14} is radioactive shortly after their formation c^{14} radio-carbon atoms combine with oxygen molecules to form carbon -di-oxide molecules green plants take carbon-di-oxide and water and convert into carbohydrate. So, every plants contains the same radio carbon c^{14}. Animals eat plants and the ring become radio- active by themselves c^{14} decay as follows

$_6c^{14} \rightarrow {_7N^{14}} + \beta +$ antineutrino

The ß detector shows count (N) in proportional the activity of the specimen.

N α R and N_0 α R_o

$\frac{R0}{R} = \frac{No}{N}$

The activity of radio carbon c^{14} from plant or animal that was recently. Dead can be found as R. If the activity of c^{14}isn age – old sample is R ,then

$$R = R_0\, e^{-\lambda t}$$

$e^{-\lambda t} = \frac{R}{R0}$

$e^{\lambda t} = \frac{Ro}{R}$

$\lambda t = \log_e \frac{Ro}{R}$

$$t = 1/\lambda \log_e \frac{No}{N}$$

$t = 2.303 * 1/\lambda \log_e \frac{No}{N}$

Since, γ is known, from the half-life of c^{14}, the value of t can be calculated.

This gives the age of the sample.

α– decay

The emission ofα – rays from radioactive element is called α – decay. The general equation for α decay is given below.

${}_{Z}P^{A} \rightarrow {}_{2}He^{4} + {}_{Z-2}D^{A-4} + Q$

Where P – parent nucleus

D – Daughter nucleus

Y – Mass number

Z - Atomic number

Q is the also called Q value of reaction

Example:

${}_{92}U^{238} - \rightarrow {}_{2}He^{4} + {}_{90}{}^{Th234} + Q$

In this above example in this thorium and U is the uranium. He is the helium, Q is the disintegration energy. In the α decay, the mass number of parent nucleus is reduced by 4 and the atomic number is reduced by 2

Condition for d – decay:

The condition is the disintegration a must be more than the potential barrier energy. That is disintegration energy must be positive. This is the condition for α-decay

Expression for disintegration energy (R)

In α – decay, the disintegration energy or decay energy is an important parameter. Let the mass of parent atom be M. Since the parent atom is at rest, the initial momentum is zero.

Then,

$$O = M_2V_2 + mv$$

$$M_2v_2 = mv$$

$$V_2 = \frac{m}{m2} V$$

Where, V_2 – velocity of daughter element

M_2 – mass of daughter element

m – mass of α particle.

Now by definition, the disintegration energy R is the sum of kinetic energies of α particles and daughter nucleus.

$$Q = \frac{1}{2}M_2V_2^2 + \frac{1}{2}mv^2$$

$$Q = \frac{1}{2}M_2\left(\frac{m}{M2}V\right)^2 + \frac{1}{2}mv^2$$

$$Q = \frac{1}{2}mv^2\left(\frac{m}{M2} + 1\right)$$

$$Q = E\alpha\left(\frac{m}{M2} + 1\right)$$

$$\frac{m}{M2} = \frac{4}{A-4}$$

$$Q = E_\alpha\left(\frac{4}{A-4} + 1\right)$$

$$Q = E_\alpha\left(\frac{4+A-4}{A-4} + 1\right)$$

$$Q = E_\alpha\left(\frac{A}{A-4}\right)$$

This shows that Q> Eα. i.e kinetic energy of Eα is always less than the decay energy Q alpha can take place when Q is Positive

Geiger- Nuttal law

(Range of α- Particle)

Geiger – Nuttal law gives range of α – Particle and it is given by

$$\log R = a \log \lambda + b$$

Where R→ Range of α- Particle

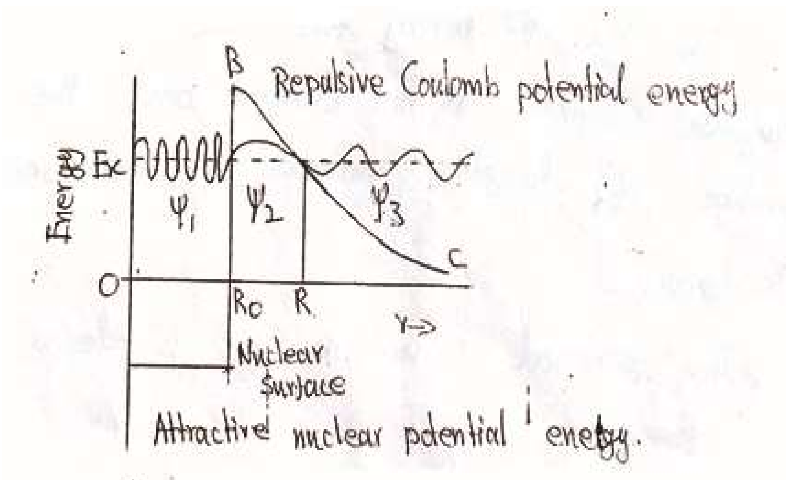
λ→ Disintegration constant

a,b -→ Constants

Explanation and theory of α decay

Uranium U^{238}, U^{234}, Th230, Ra 226, Rn222, P_O218,

are all α decay emitters. It is responsible to assume that the alpha particle exists inside type even before the decay theα particle emitted in α – decay comes from inside the nucleus. Where the α particle is held in by an attractive force. Once outside the nucleus, the α – particle is repelled by the coulomb force. The potential barrier of the α – dray emission is 26 Mev. The diagram for tunnelling effects is given below.



The penetration of α – particles through the barrier is knows as. Tunnelling effects or quantum mechanical tunnelling.

β – decay:

The emission of β – rays from radioactive elements is called β – decay.β – rays consists of electronic β – rays have negative charge. There are two types of β – decay.

1.β^- – decay

2.β+-decay

β^- –decay

The general equation for β – decay is given below

$$_ZP^A \rightarrow _{Z+1}D^A + e^- + Q$$

Where, P – Parent nucleus, D – Daughter nucleus

E – Charge of β rays, z – atomic number

A – Mass number

Examples.

$$_{90}Th^{234} \rightarrow _{91}Pa^{234} + e^- + Q$$

Pa→Protactinium

In this β decay the mass number of daughter element is not changed and the atomic number of daughter nucleus is increased by 1β^+

The general equation for β^{+-} decay is given below

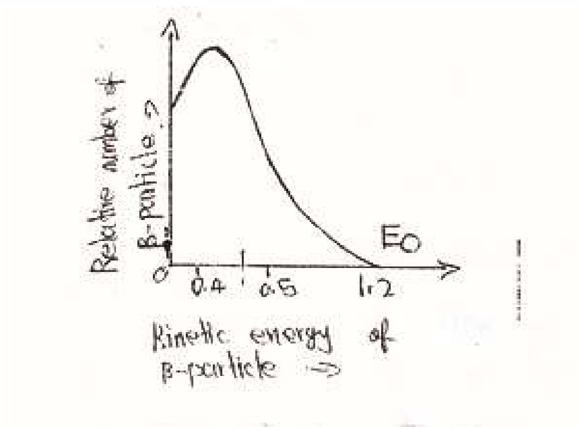
$$_{Z}P^{A} \rightarrow _{Z-1}D^{A} + e^{+}$$

Where e^+ positron

The antiparticle of the electron is position and it has positive charge

β– ray spectrum

A graph is drawn between relative number of ß particles and kinetic energy of ß particles and it is called as ß ray spectrum



Observation:

(i) The spectrum shows continuous distribution of energy from zero b maximum value Eo
(ii) Another important feature of β – decay is that the linear momentum and angular momentum are fauns not be conserved.

Theory of β – decay:

The nucleus is a quantum system and this energy is discrete. A transition between two different nuclear states happens during nuclear decay. So the energy released in radioactivity decay must be discrete. The energies of α de agreed with this understanding, now how can the β– energy spectrum be continuous, if energy conserved.

The decay energy (Ec) must be distributed among the electron (e), the neutrino γ and the daughter nucleus (d).

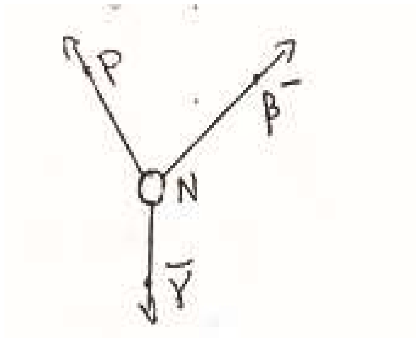
$$E_o = E_e + E_\gamma + E_d$$

Where, E_o is constant:

Then the continuous distribution of energy be accounted for if may be also happen that a nuclear proton supplied with sufficient energy decays into a neutron by β - decay and neutrino emission

$$P \rightarrow n + e^{+} + \gamma$$

Where, e^+ is the position that is identical with electron but carrying positive electric charges.



Basic reaction in β – decay.

β - decay

In this curve, a neutron is converted into proton with the emission of electron and in

The equation is antineutrino

$$n \rightarrow P + e^+ + \gamma^-$$

In the above equation n– is the neutrino P is the proton, e is a electron (or) β– particle, and y is the antineutrino

β^{-T} decay

In this case, A proton is converted into as neutron with the emission of positron and neutrino.

$$P \rightarrow n + e^+ - \gamma$$

In the above equation y is the neutrino and e^+ is the position.

Electron Capture:

Here an electron is captured by a proton. The equation for electron capture is

$$P + e \rightarrow n + \gamma$$

Inverse β – decay

The equation for β^-decay is $n \rightarrow P + e^+ + \gamma^-$

The equation for β^+decay is $P \rightarrow n + e^+ - \gamma$

Therefore, the equation for inverse β – decay are,

$$P + \gamma^- \rightarrow n + e^+$$

And second equation as

$$n+\gamma \rightarrow P+e^{+}$$

γ – decay or (Gramma decay):

The emission of r – rays from as radioactivity element is called as r – decay. THE R – consists of photons. R – rays have no charge. The general equation for gamma decay is,

$${}_{Z}P^{A*} \rightarrow {}_{Z}D^{A}+\gamma \text{ --- rays}$$

In the above equation p is the parent nucleus D is daughter nucleus and P* is the unstable (or) called excited nucleus.

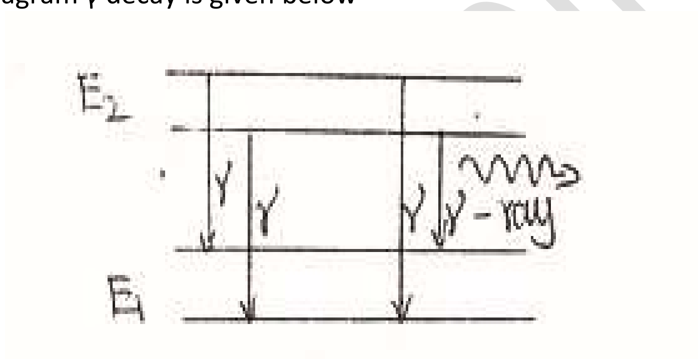
EXAMPLES;

$${}_{38}Sr^{*} \rightarrow {}_{38}Sr^{97}+\gamma\text{- rays}$$

In the above equation Sr is the excited strontium nucleus

Transition:

Nuclei are in the quantized energy states nuclear levels. When an exited nucleus from lever jumps to grounds state (lower level) γ rays are emitted. This is known as transition of nuclei. The energy level diagram γ decay is given below

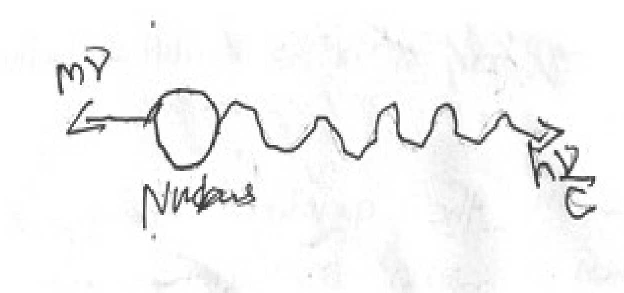


In the above diagram, there are two nuclear levels. The energy of upper level is E_2. The energy of lower level is E_1. γ rays are emitted in the diagram.

Important points;

(i) The atomic number of a parent nucleus and daughter nucleus is the same.
(ii) The mass number of parent nuclear and daughter nucleus in the same
(iii) When parent nucleus move from upper level to lower level, γ rays is emitted.
(iv) The spin values of parent nucleus and daughter nucleus are different.

The diagram for γ – rays is given below



Energy of γ – rays photon:

The energy difference is,

E_2-E_1= hγ+ ½ mV^2

Or

E_2-E_1= hγ$\frac{p2}{2m}$

Where, h – planks constant, ϑ – frequency, M – mass

P – Momentum

E_2-E_1= hγ $(\frac{h\gamma}{c})^2$/ 2m

Photon energy= hγ $(1 + \frac{h\gamma}{c})^2$/ 2m

Neutrino and its properties;

(i) Neutrino is neutral particle
(ii) Anti particle of neutrino is antineutrino.
(iii) Neutrino are emitted from β– decay.

Types of neutrinoes:

(i) γe and $\gamma^{-}e$ (ii) γ_μ and $\gamma^{-}\mu$ (iii) γ_τ and $\gamma^{-}\tau$

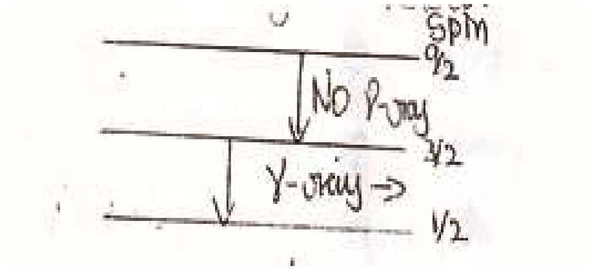
Properties:

(i) Neutrinoes have no charge.
(ii) Neutrinoes have very little mass (almost) zero.
(iii) Neutrinoes have no magnetic moment.
(iv) Neutrinoes have spin.$(\frac{1}{2}\hbar)$
(v) Neutrinoes are not deflected by electric and magnetic field.
(vi) Neutrinoes have weak interaction.
(vii) Neutrinoes can penetrate deep into matter.
(viii) The helicity of neutrino is negative. He of antineutrino is positive.
(ix) Neutrinoes belong to lepton family.

Nuclear isomerism:

The study of nuclear isomers is called as nuclear isomerism nuclear isomers have some atomic number and same mass number. But they have different spin values.

For example, in γ decay the exited nucleus and ground state nuclear are the nuclear isomerism. The energy level diagram for nuclear isomerism is given below.



In the above diagram, there are three nuclear spin levels. For γ – ray emission the spin difference must be low. When nucleus moves from spin states to ½ spin state γ– ray are emitted.

Important points:

(i) Nuclear isomers have same atomic number.
(ii) Nuclear isomers have same mass number.
(iii) Nuclear isomers have different spin values.
(iv) Nuclear isomers are in different spin state.
(v) Nuclear isomers have different energy.

Mass Bauer effect:

This effect was discovered by Rudolf Mass bauer in 1958.

It is used in the basic research of physics and chemistry. This effect is used to measure

Small energy changes in nuclei, atoms and crystals induced by gravitational, electric and magnetic fields. This effect is also called as recoil– free gamma ray resonance absorption statement.

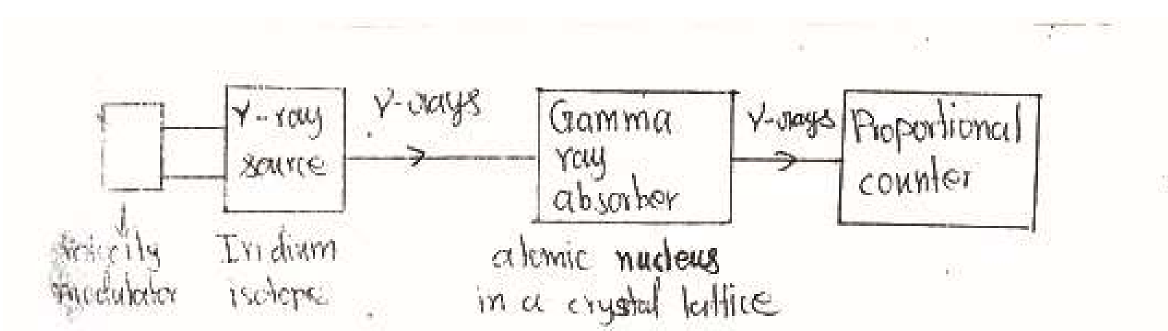
If the atomic nucleus is fixed in a crystal lattice, the nucleus absorbs or emits γ– rays without less of energy. Here recoil energy is not lost. This is called as the moss buyer effect when y – ray are observed, it is called resources absorption.

Experimental arrangement:

It consists of

1. Gamma ray source.
2. Gamma ray absorber fixed in a crystal.
3. Velocity modulator.
4. Proportional counter etc.

The diagram is given below.



Here iridium isotopes are used as the gamma ray sources. The velocity modulator is used to move the gamma try source is forward or in backward direction. The gamma ray absorber

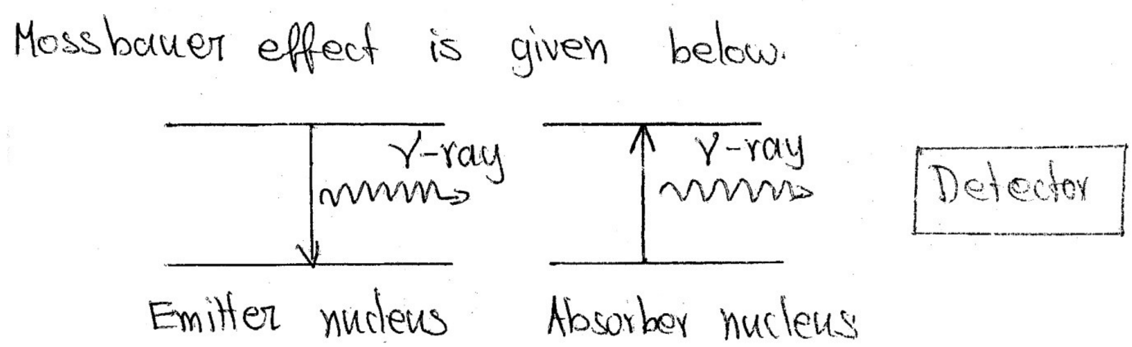
(Atomic nucleus) is fixed in a crystal lattice to avoid the recoil energy loss. The emitted γ rays are measured by the proportional counter.

When the gamma ray observed in a crystal lattice, there is no recoil and hence there is no recoil atoms energy.

Application of Mossbauer Effect

(i) This effect is used to measure the energy charges in nuclei and atoms.
(ii) It is used to measure the gravitational. Red shift.
(iii) If is used to measure isomers shift, temperature shift and Zeeman nuclear shift.
(iv) If is used for chemical identification.
(v) This effect is used to hyperfine structures and states matter.

This spectroscopy uses the Mossbauer effect recoil less gamma ray emission and absorption. If gives information about chemical magnetic structural and time dependent properties of materials. In Mossbauer effect loss of recoil energy is eliminated by fixing the atomic nucleus in a crystal lattice. The energy level diagram for Mossbauer effect is given below



Gamma ray emitters used for Mossbauer Effect are Iridium – 197 and Fe^{57}

Radioisotopes and their users:

Isotopes have the same atomic number (same number of protons) by they save different mass numbers. Radioisotopes emit ionising radiations like α – rays, β – rays and γ– ray.

They are classified into.

(i) Natural radioisotopes.
(ii) Artificial radioisotopes.

Natural radioisotopes:

They occur in nature like uranium, thorium and c^{14}

Artificial radioisotopes:

They are made artificially. Examples CO^{60}, P^{32}, Ir^{192}. They are produced by using reactors or accelerators. Radioisotopes do not stable and they emit radiations users of radioisotopes:

Medicine:

Radioisotopes are used in diagnosis and treatment of diseases. They are used in sterilization of instruments. They are used for the treatment of lumours and cancer.Iodine-131 is used for lapirtatment for thyroid cancer. Radium - 223 is used for cancer treatment.

Industry:

Radioisotopes are used for stress testing, welding, to measure thickness of materials, testing aeroplanes and etc.

Agriculture:

Radioisotopes are used in player or disease control and food conservation.

Research:

They are used in research in colleges, universities, medicine, etc.

Imaging systems:

Radioisotopes are used for nuclear imaging systems. A radio isotope in given or injected to the body and the gamma is used to defect nuclear incurring to measure blood flow and to defect.

Archaeology:

Radio carbon dating is used to measure the age of the old samples like dead trees, building, mummy, old pots, dead animals, etc. Here c^{14} isotopes are used.

Yukawa' Meson theory of nuclear forces:

Nuclear force is the stronger, short range and attractive force. It is used to bind the neutrons and practice in the nucleus. For binding the protons and the neutrons in the nucleus, the particle like points or π - mesons considered. There are three types of points and they are π^+, π^- and π^o – mesons.

According to meson theory

(i) A Neutron emits π particle and it becomes a proton.

$$n \rightarrow P + \pi^- \quad \text{Or} \quad n - \pi^- \rightarrow P$$

This leads to $P - \pi^- \rightarrow n$

(ii) A Proton emits π + particle and it is changed into neutron.

$$P \rightarrow n + \pi^{-} \text{ Or } P - \pi^{-} \rightarrow n$$

This lead to $n + \pi^{-} \rightarrow P$

There are three types of interaction in nucleus.

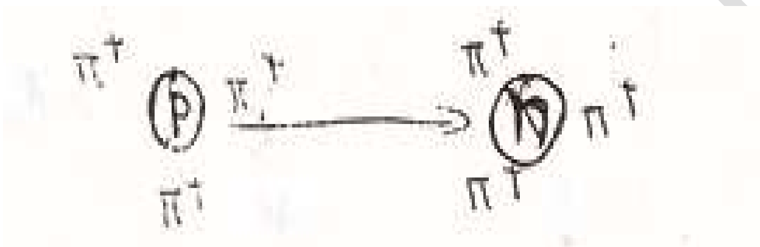
(i) Proton – Neutron interaction

(ii) Proton – Proton interaction

(iii) Neutron – Neutron interaction

Exchange of mesons:

The nucleus is surrounded by means (π^+, π^- and π^0) Mesons are responsible for producing strong nuclear force in the nucleus. Protons And neutrons share or exchange mesons and due are held together in the nucleus.



UNIT - III
NUCLEAR REACTION

ATOM BOMB:

Atom bomb is nuclear device that is based an nuclear fission. In an atom bomb, uncontrolled nuclear fission takes place.

Hydrogen bomb:

Construction:

It is also called as the thermonuclear bomb an he is based on nuclear fusion and fusion. It consists are mainly two parts.

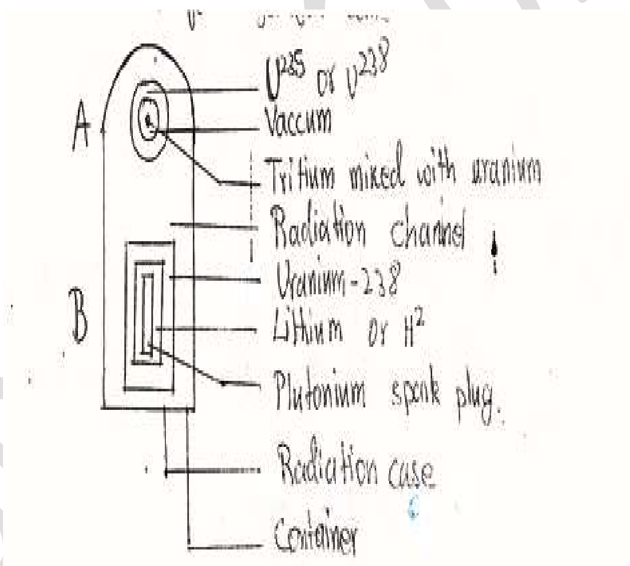
(i) Primary stages (Nuclear fission stages)

(ii) Secondary stages (Nuclear fission stages)

Fission primary stage:

The fission explosion is started by using the fission primary stage. The primary stages consist of nuclear fuel like heavy uranium or plutonium -239. The temperature of the primary stages will be about 10^8.Helium secondary fusion stage will be $300x10^6$K

The diagram for hydrogen bomb or fusion bomb is given below.



Both A and B are kept in the container or radiation

Principle:

Hydrogen bomb is based on both nuclear fusion as fission. The primary stage is based on nuclear fission as secondary stage is based on nuclear fission. The energy released by te primary stage is used for igniting the stage of energy.

Types of energy:

Four types of energy are produced.

(i) Expending hot gases (Thermal energy)
(ii) Super head plasma energy.
(iii) EM radiation energy.

(iv) Production of neutron energy.

Initially fission bomb (primary sage) explodes and large amount of energy is released. The energy related in the primary stage is transferred to be secondary stage. (Fission stage) This energy compresses his fission fuel and plug and fusion reaction takes places in the secondary stages. The fusion fuel is by uranium or plutonium in the secondary stages.

(i) It is used to produce a large amount of energy

(ii) It is used to produce neutrons. The reaction used in time.

$${}_1H^1 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 + \text{Energy}$$

Destruct purpose:

Hydrogen bomb creates the energy more them than atom bomb hence a high destruction created.

Kinematics of nuclear reaction:

Types of nuclear reaction.

(i) (P, γ) reaction:

The example is given below.

$${}_1P^1 + {}_3Li^7 \rightarrow {}_4Be^8 + \gamma$$

In the above example P – is the proton γ is the gamma particle, Hence , proton is the project , gamma particle is the outgoing particle , Li is the target nucleus and Be is the product nucleus.

(ii)(γ , P) reaction (proton disintegration)

The example is given below.

$$\gamma + {}^{25}Mg \rightarrow {}^{24}Na^* + {}_1H$$

(iii) (n,γ) reaction :(Radioactive capture)

The example is given below.

$${}_0n^1 + {}_{13}Al^{27} \rightarrow {}_{13}Al^{28*} + \gamma$$

(iv) (d, p) reaction

The examples is given below

$${}_1H^2 + {}_6C^{12} \rightarrow {}_7N^{*14} \rightarrow {}_6C^{13} + {}_1H^1 \text{ (Proton)}$$

Q– Value of a nuclear reaction:

When a projectile collides on a target nucleus a product nucleus and an outgoing particle are produced. This is known as nuclear reaction.

The nuclear reaction is given below by

X+X-→ y+ Y

x – is the projective

X – is the target nucleus.

y – is the outgoing particle.

Y – is the product nucleus.

In start form,

X (x,y) Y

Total energy before reaction = $(m_x c^2+k_x) + (M Xc^2+k_X)$

Total energy after reaction = $(m_y c^2+k_y)+(myc^2+k_y)$

Where

Mx - Mass of projectile

C - Velocity of light

Kx - Kinetic energy of projectile

Mx - Mass of target nucleus

Kx - Kinetic energy of target nucleus.

My - Mass of outgoing particle.

Ky - Kinetic energy of outgoing particle.

My - Mass of product nucleus.

KY - Kinetic energy of product nucleus.

Applying the law of conservation of energy.

$m_x c^2+k_x + M_X c^2+k_X = m_y c^2+k_y+myc^2+k_y$

Now Kx= 0 since the target nucleus at rest

$m_x c^2+M_X c^2- m_y c^2-myc2= k_y+k_Y-K_x$

$m_x c^2+M_X c^2- m_y c^2+myc^2= k_y+k_{Y+}K_x$

$[(m_x+M_X) – (m_y+My)]= (k_y+k_Y)-K_x$

Q Value is the reaction energy

$Q = [(m_x+M_X) – (m_y+My)] = C^2$

This is expression for Q – value of nuclear reaction from eqn this same as.

Equation 2 is the re – written as

$Q/C^2 = [m_x +M_X – (m_y + M_y)]$

(i) When Q = 0 no nuclear energy is released and the reaction is an elastic collision.

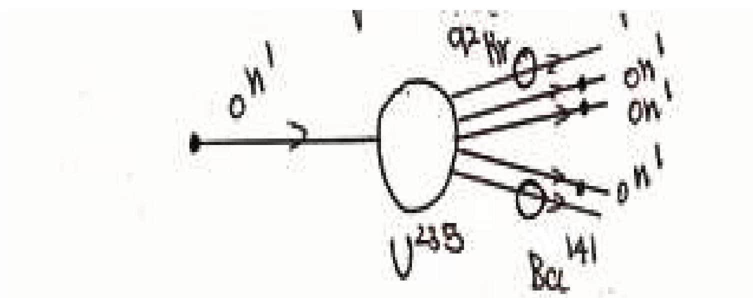
(ii) If Q > 0, Nuclear energy is released. Such a reaction is known as exoergic.

(iii) If Q <O the reaction is endoergic.

Nuclear fission.

When a heavy nucleus splits into lighter nuclei, it is called, nuclear fission when a neutron collides on a radioactive material like uranium,

B_a and K_r are produced. The example is given below.



In the above diagram, the projective is the slow neutron, target nucleus is uranium, product nuclei are β and the outgoing particle are neutrons.

Importance points:

(i) Nuclear fission is the principle of nuclear reactor and atom bomb.

(ii) The energy released per nuclear fission reaction is200 MeV

(iii) Only slow neutrons are used in the above nuclear fission.

Energy receiver from nuclear fission:

Mass defect (ΔM) = Total mass before reaction – total effect reaction.

ΔM =ΔM amu

Energy released = $(\Delta m) x c^2$ joules

Energy released = ΔM X 931 MeV

From the nuclear fission the energy released is 200MeV

Problem:

Calculate the energy released from u^{225} in fission?

Nuclear fission equation is

$$_On^1 + {}_{92}U^{235} \rightarrow {}_{141}Ba + {}_{Kr}{}^{92} + 3_On^1$$

Mass of neutron = 1.00965

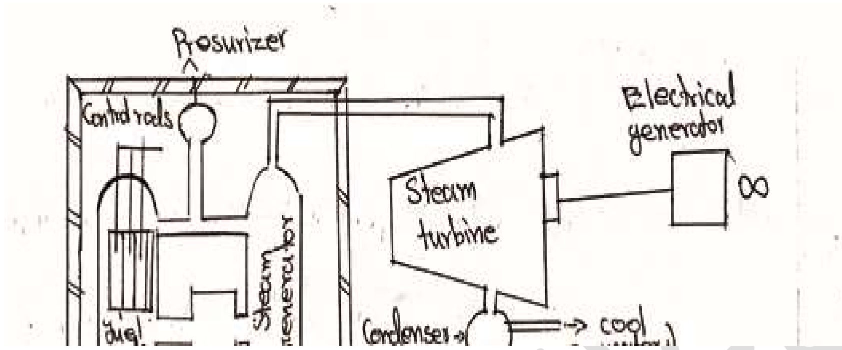
Mass of U = 235.0632

Mass of kr = 92.00234

Q – Value = (input total mass – output total mass)* 931 MeV

Nuclear reactor:

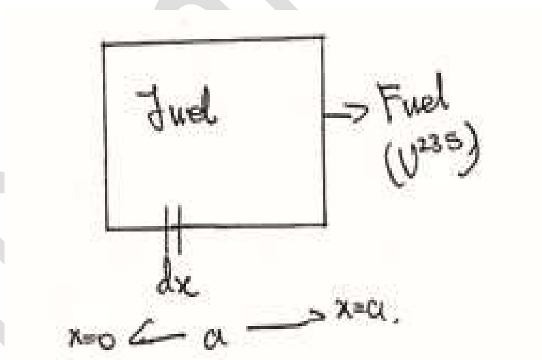
The nuclear reactor is used to general the electricity to produce neutrons and to produce the radioactive materials. The diagram for nuclear reactor is slow below.



It mainly consists of

(i) fuel (U^{235})
(ii) Moderator
(iii) coolant
(iv) control rule

The fuel container is shown below.



In the diagram, a – the size (or) length of the return x=o, x= a – the boundary conditions.

When a return collides on a uranium nucleus, kr, βα and neutrons are produced. A neutron balance equation is

Neutron Production rate= neutron leakage rate + neutron absorption rate

Neutron leakage rate $= \frac{-\lambda tr\ v}{3}\frac{d2n}{dx2}$ dx

Uses:

(i) Nuclear reactor is in production of electricity.

(ii) Production of isotopes.

(iii) It is used to increase electrical energy demand in a country.

(iv) It gives employment to the people.

Nuclear fusion:

When two lighter nuclear are combined to form a compound nucleus is called nuclear fusion.

$$_1H^2 + _1H^2 \rightarrow _2He^3 + _0n^1 + \text{Energy}$$

Energy released from the nuclear fusion:

Mass defect =Total mass before reaction – Total mass after reaction

Energy released = Δmc2

When two deuterium (Heavy hydrogen) are combined a helium nucleus is formed.

The mass defect =0.004 amu

The energy released=Δm * 931 MeV

Thermo Nuclear reaction:

Nuclear reaction that takes place at very high temperature are known as thermo nuclear reaction.

When two deuterium (heavy hydrogen) are combined, α helium nucleus is formed. This reaction will table place at very high temperature, in the sum, nuclear fusion or thermo nuclear reaction will table places. In the fusion reaction high energy is released. For nuclear fusion large amount of heat is necessary.

Examples:

Hydrogen bomb:

From thermo nuclear reaction radioactive produced are not formed. Thermo nuclear reaction is classified into.

(i) Controlled thermo nuclear reaction.

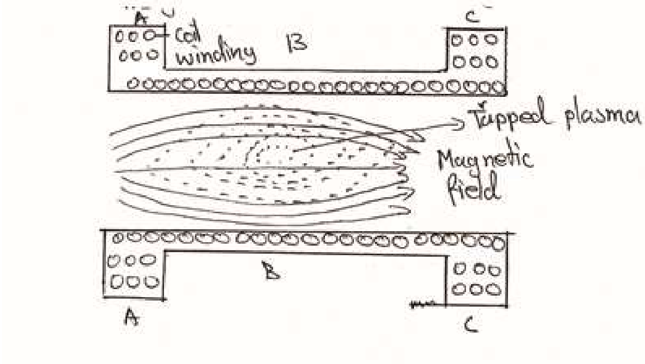
(ii) Uncontrolled thermo nuclear reaction.

(i) Controlled thermo nuclear reaction:

The plasma is an electrically neutral or a collection of ionised atoms, molecules or electrons. It may be produced in various ways you examples, by discharge of electricity table. The plasma temperature is required for nuclear fusion reaction (controlled thermo nuclear reaction) can be secured by keeping the plasma in a container and the reaction can be made to happen in the plasma reaction.

Plasma confinement:

It is desirable to confine the plasma with the help of a strong magnetic field. By this way container problem is solved and another purpose is also served. The fission reaction can be made to happen in a controlled way. The diagram for magnetic bottle is given below.



It consists of,

(i) Coil winding
(ii) Trapped plasma
(iii) Magnetic field

A magnetic field is used for confinement of plasma in between the coil windings. It is used to control thermo nuclear reaction.

By increasing or decreasing the current in the filed coil A,B, and C the field shapes can be modified at our coil and the plasma can be winded or narrowed by decreasing the field at the right end and gradually increasing the fields from left to right the plasma can be transported length wise from one table to another.

(i) Fusion reactor

Fusion reactor is the most promising device in which controlled nuclear fusion can take place.

(ii) Fusion reaction:

The following reaction can be possible made be happen in a fusion reactor.

a) Deuteron – deuteron reaction such as

$${}_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 \text{ with } Q = 3.7 \text{ MeV}$$

(iii) Conditions for fusion reaction and Lawson's criterion:

The conditions are,

a) The number density (n) of the plasma must be sufficiently large.

b) A high plasma temperature (T) must be maintained.

c) A long confinement time (T) must be large.

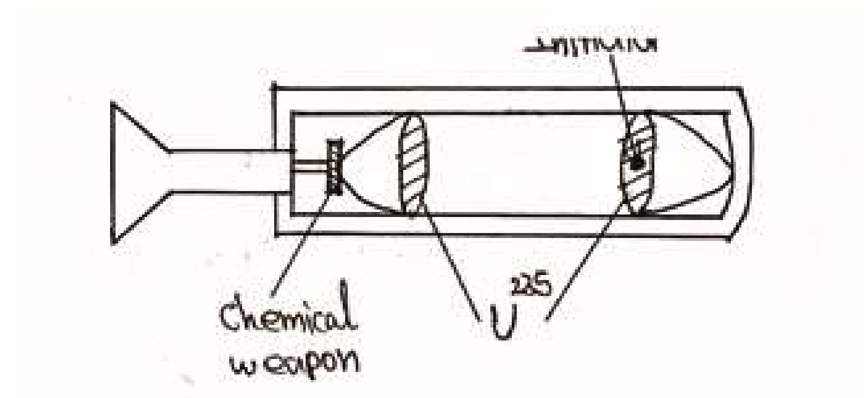
For successful operation of a nuclear fusion reaction, it is necessary to have

$n\,\tau \geq 10^{20}$ S/m^3 and T= 10 KeV

This condition is called Lawson's criterion

Atom bomb (Fission bomb):

The atom bomb works on the principles of nucleus fission and uncontrolled chain reaction. The simplest design of atom bomb is the gun type as shown below.



56 Some isotopes of polonium is mixed with the beryllium in order to increases the neutron flue.

The casing of the bomb is a sturdy material. The casing services the purpose of keeping the super critical masses together of as long as possible, in order that as much as possible amount of U-235 undergoes fission, thereby increasing the weapon's yield. Depleted uranium (U-238) is an excellent choice of the casing material. U-238 can also

(i) Reflect some of the neutrons back to U -235 and
(ii) Interact with fast neutrons and produce fission.

The proper name for U -238 used in this way is tamper:
When the atom bomb is dropped, the chemical explosive accelerates one hemisphere towards the other. Supercritical mass of U – 238 is formed and at the same time the neutrons imitiator work to produce high neutron flue. Chain reaction takes place in an uncontrolled way and the bomb explodes. The explosion of the atom bomb release a large quantity of energy in the form of heat waves, light rays, neutron beams and powerful gamma rays. A temperature of million degrees and a pressure of million atmospheric pressure are smashing soil, buildings, human life, animals and plants. The release of radioactive rays during the bomb explosion passes.

Hydrogen bomb (or) H-bomb;

Principle;

Nuclear fusion is the principle of hydrogen bomb. The equation for nuclear fusion is given below.

$$_1H^2 + {}_1H^2 \rightarrow {}_2He^3 + {}_0n^1 + \text{energy.}$$

3.7 MeV energy is released per nuclear fusion. High temperature is necessary for nuclear fusion.

Construction;

Hydrogen bomb consists of two stages.

(i) Primary stage.

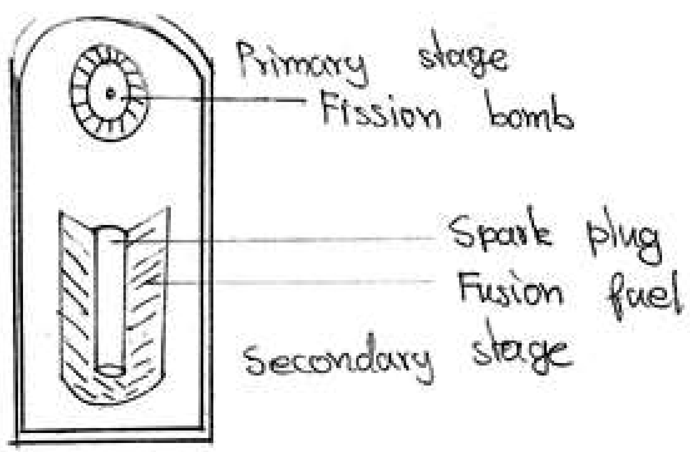
(ii) Secondary stage.

Primary stage.

Here primary explosive will take place. This is called as the nuclear fission stages. This stage produces a lot of heat (temperature) for fusion process.

Secondary stage.

Here secondary explosive will take place. This is called as the nuclear fusion stage. Here hydrogen nuclei are fused. The diagram for the hydrogen bomb is shown below.



Working:

Heat is generated in the primary fission stage. This heat is used for fusion process. In the secondary stage, fusion fuel (hydrogen) is taken. Using spark pkg the hydrogen bomb is explained.

DEMERITS;

(i) Hydrogen bomb will destroy buildings, plants, animals and everything.

(ii) High temperature is necessary for fusion process.

(iii) Fission bomb is necessary for triggering the hydrogen bomb.

MERITS;

(i) Hydrogen bomb can produce a lot of energy.

(ii) It will not produce radioactive materials.

Soddy = fajans'sd displacement law;

This law is also called as the radioactive displacement law.

(i) In alpha decay (alpha ray emission), atomic number is reduced by 2 and mass Number is reduced.

Working;

The fuel element (u^{235}) undergoes spontaneous fission. The control rods are now pulled out in order to minimise neutron capture (neutron less). Energy is produced in the reactor and tapped for useful purposes such as heating water and produce steam.

On the other hand, if each fission reaction produces more than one further fission, the reactor is said to be super – critical. The nuclear energy of 200 MeV per fission will appear mostly in the form of kinetic energy of fragments and kinetic energy of neutrons and gamma radiations.

To increases the efficiency of working of the reactor, the loss of neutrons from the uranium fuel block must be minimised.

Loss of neutron α the surface area.

Surface area, $s = 6a^2$ for the sin faces of the cubical block.

Volume, $V = a^3$

$$\frac{s}{v} \text{ ratio} = \frac{6a^2}{a^3} = \frac{6}{a}$$

Hence to minimise the surface area, the side (a) of the cube must be heat lase.

Uses:

Nuclear reactor can be used.

(i) For power generation
(ii) As neutron source
(iii) For production of ratio – isotopes.
(iv) For production of fissionable materials.

UNIT - IV
NUCLEAR DETECTOR AND PARTICLE

ACCETERATORS

Geiger – Muller Counter (G.M counter):

G.M .Counter is used to defect and count α, β and V radiations

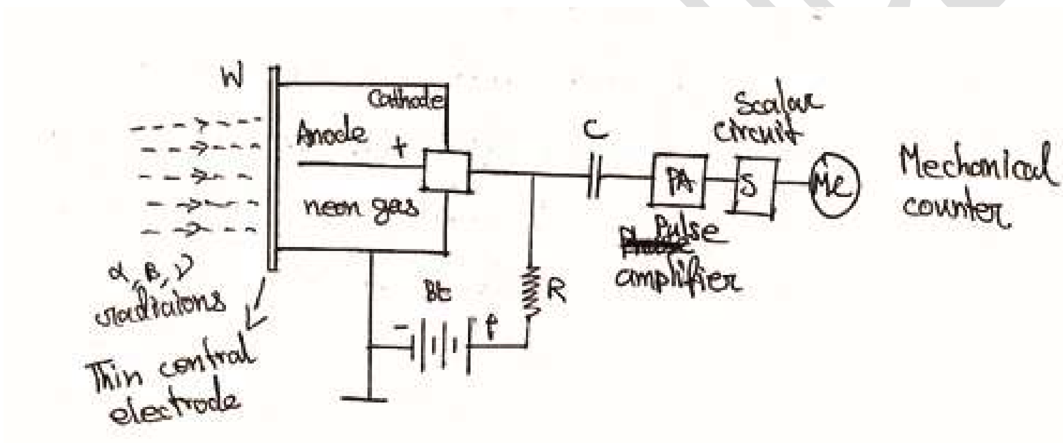
Principle:

When α – rays, β – rays & v – rays pass through a gas like neon as, the gas is ionised.

When a high D.C voltage of 1000v is applied, high ionization is created. By measuring the count rate [(count / sec)] the radiations are deflected.

Construction:

The diagram for G.M Counter is given below,



It consists of,

(i) Cylindrical metal tube.
(ii) Anode (tungsten wide)
(iii) HT battery
(iv) Capacitor and resistor (C&R)
(v) Pulse amplifier
(vi) Scale circuit

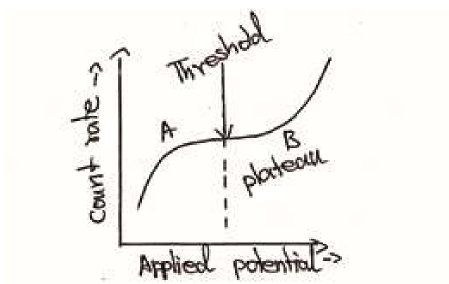
58The cylindrical tube contains neon gas. The anode is a tungsten wire. The cathode is a cylindrical metal tube. A HT battery is connected between made and attack.

The resistance is used to control the AC signal. The amplifier is used to amplify AC signal into digital. The mechanical counter is used to measure the count rate of radiations.

Working

α, β , rays are passed to the neon gas through the mica window (w). The neon gas is ionised. When a high mica window will increased. There will be electrons and positive ions the cylindrical tube. The electron and positive ions in the cylindrical tube. The electrons more a mode towards cathode. The count rate is measured at different applied voltages.

A graph is drawn between the count rate and applied voltage.



The above graph is called characteristics of G.M Counter the region AB is called plateau region. The threshold voltage. The ionization takes place due to avalanche of electron. The ionizing radiations are detected using the counter.

Uses:

(i) G.M counter is used to detect α – rays, β – rays and γ – rays
(ii) It is used to find range of α – particles
(iii) It is used to verify inverse square law for gamma radiation.
(iv) The inverse square law is given by ,
$I \alpha \frac{1}{d^2}$ or $I = \frac{K}{d^2}$

Where,

I - intensity

D - distance

k - Constant.

(v) It is used to find the linear absorption co-effficient
(vi) It is used to find the thickness of a paper in paper industries.

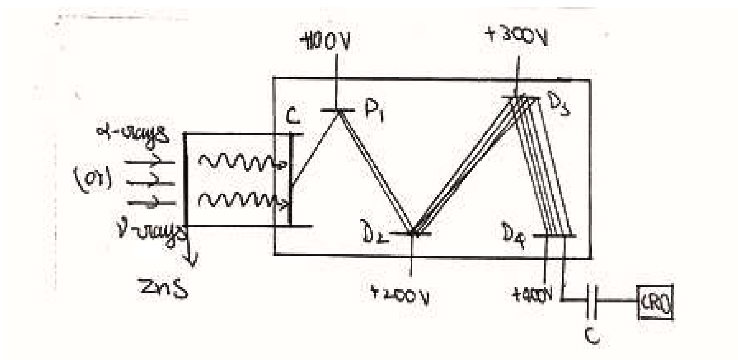
Scintitation counter.

It is used to detect α – rays and γ rays

Principle

When α – rays (or) y – rays collide on a surface of fluorescent materials like zinc sulphide (zns), flash of light is produced. The flash of light is called scintillation. Using a photo multiple tube (PMT) α – rays and y – rays are detected.

Construction;



It consists of

(i) Scintillator (zns)
(ii) Photo cathode (c)
(iii) PMT
(iv) Dynodes $(D_1D_2D_3D_4etc)$
(v) CRO
(vi) Capacitor
(vii) HT battery

Scintillator is kept in front of PMT. The PMT consists of the photo cathode and dynodes $(D_1D_2D_3D_4etc)$. Photo cathode (c) is a earthed. The dynodes are given +ve voltages. The dynotesD_4 is connected as shown in figure.

Working

(i) When α – rays collide on a florescent material like zns, a flash of light is produced.

When the flush of light is falls on the photo cathode, photo electrons and emitted. This is known as photo electric effect. The photo electron are multiplied using the dynodes $(D_1D_2D_3D_4etc)$ the amplified electric signal is passed through the capacitor and to the CRO. The visualized electric signal is seen on the CRO. Hence the high electric

User

(i) it used to defect r – rays very easily
(ii) it is used to defect thermal neutrons,
(iii) A few photos can also be defected.

Wilson cloud chamber.

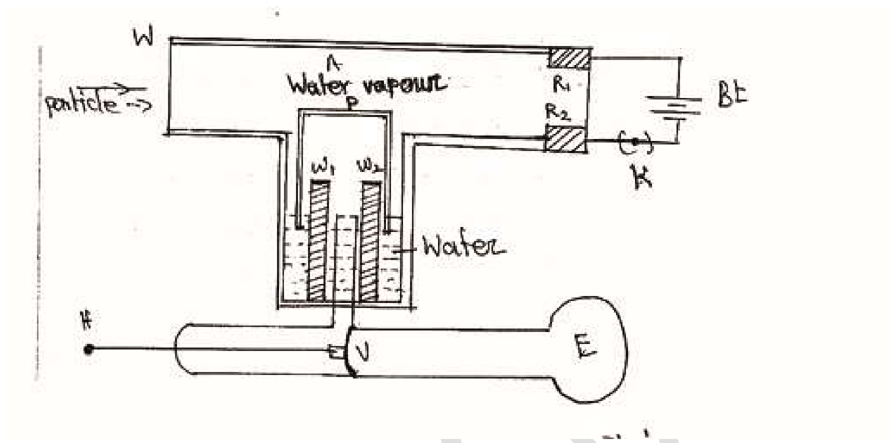
It is used to take photo graphs of high energy particles and cosine rays.

Principle

Expansion of water vapour causes cooling. This is the principle of cloud chamber. When water vapour is cooked, water drop are formed along the track of particle in the cloud chamber. The droplets are photographed using a camera.

Construction

The diagram of Wilson cloud chamber is given below.



It consists of,

(i) Cloud chamber
(ii) Plat – form
(iii) Evacuated chamber
(iv) Value (v)

The cloud chamber contains water and water vapour. A plat – form (p) us kept inside the cloud champer. The wooden plugs $(w_1 w_2)$ are placed in the cloud. The evacuated chamber (F) is attached to the cloud chamber. The battery and key are connected to the metal rings.

Working

High energy particles are allowed to enter the cloud chamber. Using a handle, the value is opened in the evacuated chamber. The plat – form (P) is droped down. The water vapour. The plot – form (p) is droped down. The water vapour move to evacuated chamber. There is an expansion of water vapour and cooling occurs water droplets formed along the track of particles in the cloud champer. Using a camera, photograph of particle is taken. A film is washed in a dark room and the track particles is seen. We can use a magnetic field to charge the track of particles. Using the battery the high energy particles already present in a chamber are cleaned.

Advantages

(i) Wilson cloud chamber is used to defect high energy particles.
(ii) it is used to energy statistics

Disadvantages

If the density of water vapour is more, the particles may not be defected.

Bubble chamber

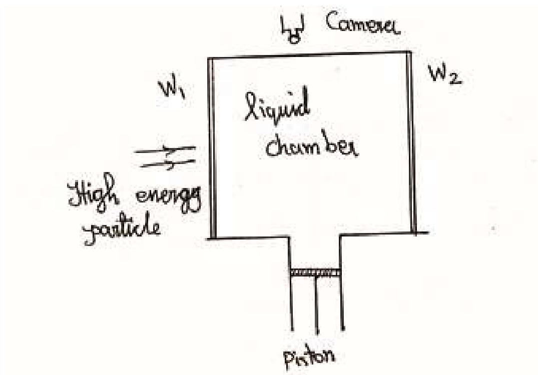
It is used to take photograph of track of high energy particles and ionising particles.

Principle

If a liquid boils above the boiling point, the liquid is called super-heated liquid. If a liquid pressure is reduced, the bubbles are firmed along the track of the high energy particle in the chamber using a camera, the track of particles is photographed.

Construction

The diagram for bubble champ is given below.



It consists of,

(i) liquid chamber
(ii) window $(w_1 w_2)$
(iii) piston camera
(iv) piston

The liquid chamber contains the super-heated liquid. The heated liquids are either, benzene, liquid to etc. the liquid the pressure is decreased. When the pressure is decreased the liquid is cooked and bubbles are formed a on the high energy particles. A photograph is taken using a camera with flash.

Working

The high energy particles are allowed to enter the bubble chamber. Using the piston pressure is reduced and bubbles are formed along the track of the high energy particles. In the chamber using a camera the track of high energy particles. In the chamber using a camera the track of high energy particles in the chamber is photographed. The film is washed and developed in the darkroom. The track of particles is seen on the film. Hence the particles are defected.

Advantages of bubble chamber over the cloud chamber:

(i) In the bubble chamber, super-heated liquid is used. But in the cloud chamber saturated water vapour is used.
(ii) Density of super-heated liquid is less in the bubble chamber. But density of water vapour is more in the cloud chamber.
(iii) Since the density of super-heated liquid is less in the bubble chambers, the high energy particles can easily be defected.

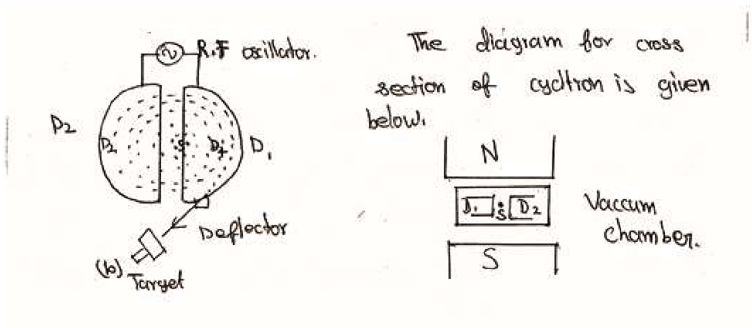
It is a particle accelerator and it has invented by Ernest Lawrence in 1934. A cyclotron is used to accelerate the positive ions, α – particles, protons and etc.

Principle:

Resource acceleration is the principle of cyclotron.

Construction:

The diagram for cyclotron.



The cyclotron consists of,

(i) Does D_1 and D_2
(ii) Positive ions source (S)
(iii) RF oscillator
(iv) Defector
(v) Electromagnet
(vi) Target
(vii) Vacuum teamer

R.F oscillator is connected between D_1 and D_2 positive ion source is kept at the centre of cyclotron. The whole arrangement is kept in the vacuum chamber. The magnetic field is applied to defect the positive ions. The deflect is used to put out positive ions from the cyclotron.

Working

(i) The positive ions are defected by electric and magnetic fields. When D_1 is negative D_2 will be positive. The positive ions more towards D_1 and it is accelerated.
(ii) When D_2 is negative, D_1 will be positive. The positive ion move towards D_2 and it is accelerated.

Under balance of force.

Magnetic force = centripetal force

$$\text{Be v} = \frac{mv^2}{r}$$

$$v = \frac{Ber}{m}$$

Where, B → magnetic field.

e→ charge of positive ion

v →Velocity of positive ion

m→ mass of positive ion

r→ radius of circular orbit.

Also we get

$$r = \frac{vm}{Be} \rightarrow 2$$

The angular velocity of the icon is given by

$$W = \frac{v}{r} = \frac{Be}{m} - 3$$

Time taken to travel on semicircle is,

$$t = \frac{\pi}{w} - 4$$

Energy of the accelerated ion:

Let R be the radius of the outermost we known that.

$$v = \frac{BeK}{m} \text{ ----------- } 5$$

Kinematic energy of positive ion,

$$E = \frac{1}{2} m v^2$$

$$E = \frac{B^2R^2}{2} = \frac{e^2}{m^2} \text{ --------} 6$$

Synchronisation condition:

Time taken for one semi-circle is $t = \frac{T}{2}$ where, T – is the period

From the equation 3 and 4,

$$\frac{\pi m}{Be} = \frac{T}{2}$$

$$\text{(Or) } T = \frac{2\pi m}{Be}$$

Frequency is $F = \frac{1}{T}$

$$\therefore F = \frac{Be}{2\pi m} \text{ --------} 7$$

$$\therefore B = \frac{2\pi Fm}{e} \text{ ----------} 8$$

We have,

$$E = \frac{B^2R^2}{2} = \frac{e^2}{m^2} \text{ --------} 9$$

Put 8 in 9. This is synchronisation condition for cyclotron.

Limitation:

(i) Cyclotron cannot accelerate electrons and β particle.

(ii) It is very difficult to maintain uniform magnetic field.

Uses:

(i) If is used in nuclear experiments.

Synchrocyclotron:

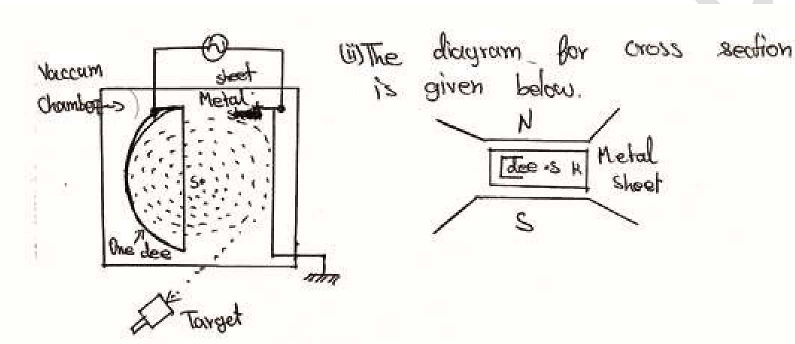
A synchro cyclotron is used to accelerate the positive ions, α - particles, proton and etc.

Principles;

Resonance acceleration.

Construction;

The diagram for synchrocyclotron is given below



It consists of

(i) Meat street
(ii) Positive ion
(iii) R.F oscillator
(iv) Magnetic field
(v) Deflector plate
(vi) Target
(vii) Vacuum chamber

Betatron:

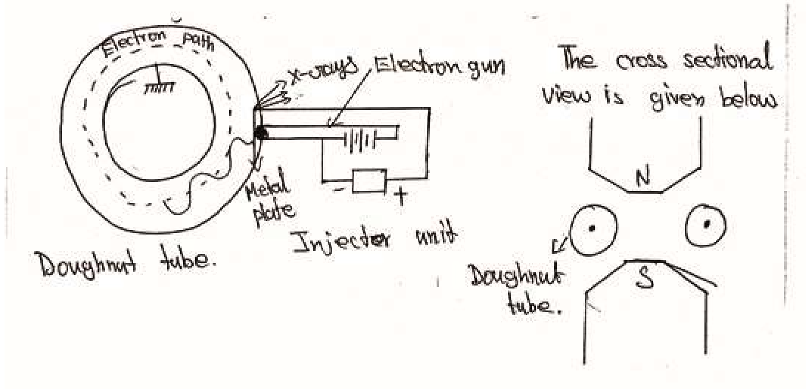
It is a particle accelerator and it was developed by Donald kersr in 1940. A Betatron is used to accelerate the electrons or –β particles.

Principle:

Electrons are accelerated and deflected by electric and magnetic fields. The maximum energy produced is 300mov.

Construction;

The diagram for betatron is given below;



It consists of

(i) Doughnut tube
(ii) Electron gun
(iii) Injector unit (I)
(iv) Strong electro magnet
(v) Vacuum chamber
(vi) Metal plate

Working:

A vacuum is created in the doughnut tube. The tube is earthed. The electron gun is kept near to the outer tube. A battery is commented to be electron gun (filament) the injector unit is a high tension battery and it is used to inject the electron in the electron bath.

A strong magnetic field is applied between the doughnut tube. The electrons are deflected by electric fields and magnetic fields. Due to electric and magnetic fields the electrons are produced from electron gun and they are accelerated.

Theory: (To obtain beta ton condition)

Consider the electron moving in an orbit of let it be the magnetic flux.(the flux linked

The rate of change of flue = $\frac{d\phi}{dt}$ by len's low

$$E.m.f=E = -\frac{d\phi}{dt}$$

The work done on the electron of charge e in one reduction is W = Ee

W = Ee

$$W = -\frac{ed\phi}{dt} \qquad \text{----1}$$

Let F be the force acting on the orbiting electing for one revolution. The path length is 2πr, the work done on the electron in one revolution is w = force x distance

$$W = F \times 2\pi r \text{ ----2}$$

Equating 1 and 2

$$F \times 2\pi r = -\frac{ed\phi}{dt}$$

$$F = \frac{e}{2\pi r}\frac{d\phi}{dt} \qquad ---3$$

Magnetic force = Bev , contributed force =$\frac{mv^2}{r}$

Equality the two forces,

$$\frac{mv^2}{r} = Bev$$

$$\therefore mv = Bev$$

By newton's second law of motion force F = rate of charge of momentum.

$$F = \frac{d(mv)}{dt} = \frac{d(Bev)}{dt}$$

$$F = er\frac{dß}{dt} \qquad ------4$$

From eqn 3 and 4

$$\frac{e}{2\pi}\frac{d\phi}{dt} = er\frac{dß}{dt}$$

$$\frac{d\phi}{dt} = 2\pi r^2 \left(\frac{dß}{dt}\right) ----5$$

This is equal to rate of change of magnetic flux integrating.

$$\int_0^0 d\phi = 2\pi r^2 \int_0^B dB$$

$$\therefore \phi = 2\pi r^2 B$$

This gives magnetic flux in electron orbit. The above condition is called Betatron Condition.

Expression for final energy;

Let C be the velocity of electron in the stable orbit from the theory of relativity,

Momentum of electron, P = $\frac{E}{C}$

$$\text{i.e } mv = \frac{E}{C}$$

Energy of electron, E = mc

for electron motion in the stable orbit ,centripetal force = magnetic force

$$= \frac{mv^2}{r} = Bev$$

Mv= Ber

Putting this value in eqn 5 energy of electron E = Ber C. This gives energy of electron maximum energy produced is 300 mev

Uses

- it is used in nuclear experiment

- it is used to produce hard x – rays.

Electron synchrotron

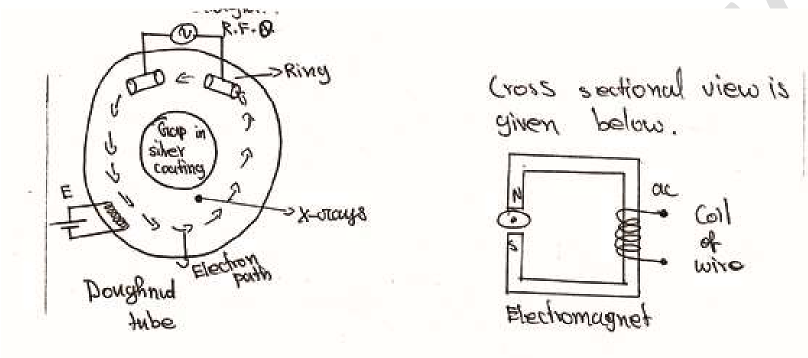
Synchrotron was developed by vladionirveksler in 1944. Electron synchrotron is used to accelerate electrons am β Particles. It was constructed by Edwin Macmillan in 1945.

Principle:

Electron are accelerated and deflected by electric and magnetic fields. The maximum energy produced in 500 mev. It is used to produce hard x – rays.

Construction.

The diagram for electron synchrotron is given below.



It consists of,

(i) Doughnut tube,
(ii) Electron gun
(iii) Metal rings
(iv) Story electromagnet
(v) Vacuum chamber
(vi) R.F .Oscillator

A vacuum is created in the doughnut tube. An electron gun is kept near to the Outer tube. A battery is connected to the filament. A magnetic fields. Due to electric and magnetic fields electrons are accelerated.

When the electron gain an energy of 2 mev an R.F oscillator is applied to increases the energy of electrons.

When the energy of electrons reaches above 400 mev electrons are allowed to Callide on the metal target and hard x – rays are produced.

Uses:

(i) Electrons synchrotron is used to produce hard x – rays
(ii) It is used for doing research.
(iii) It is used to produce high energy electron (500 mev)
(iv) It is used in x – rays lithography and metal imaginary.
(v) Energy produced is 500 mev

Proton synchrotron:

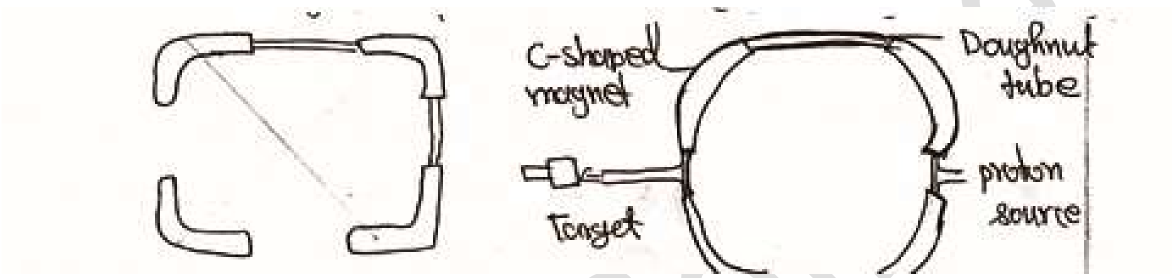
It is a particle accelerator, used to accelerate protons. It is was developed by CERN in 1959.

Principle:

Protons are accelerated and deflected by electric and magnetic fields. The maximum energy produced is 500 Gev

Construction and working;

The diagram for proton – synchrotron is given below.



It consists of,

(i) C- shaped magnet (
(ii) Short tube (connecting tube)
(iii) Proton source
(iv) Target
(v) Deflector magnet ,etc

Proton synchrotron has four C – shaped magnets are they are connected by short tubes. The vacuum is created in the proton synchrotron. Proton are obtained from proton source and they are injected through injector tube. Protons are deflected by electric and magnetic fields. The protons move in a circular path.

When they move in a circular path,

Magnetic force = centripetal force

$$Bev = \frac{mv^2}{r}$$

$$v = \frac{Ber}{m}$$

Where, B magnetic field, e – proton charge, r – radius of circular path, m – mass of proton. Using the above equation, velocity of proton is calculated.

Uses:

(i) It is used for nuclear transmutation, experiments
(ii) In transmutation, one element is converted into another element.
(iii) Energy produced in 30 GeV.

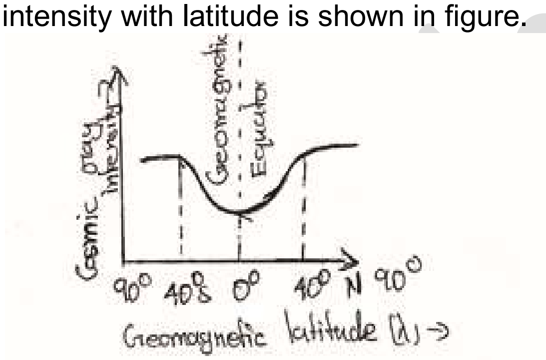
UNIT - V
DISCOVERY OF COSMIC RAYS

Cosmic rays are highly penetrating radiations which are continually entering the earth's atmosphere in all directions from outer space. Cosmic rays consist of high energy charged particles. Most of these particles have energy of the order of 15 GeV.

Cosmic rays were first defected by Elster and Geital and by C.T.R. Wilson in 1900. It was concluded that some kind of penetrating rays were entering the earth's atmosphere from outer space in all directions. There were named as cosmic rays by million

Latitude effect:

The variation of intensity of cosmic rays with latitude is called as latitude effect. The variation of cosmic ray intensity with latitude is shown in figure.



The cosmic ray intensity is maximum at the geomagnetic poles (λ = 90^0) and minimum of the geomagnetic equator (λ = 0).The intensity remain constant between 42^0 and 90^0 .This variation of cosmic ray intensity with geomagnetic latitude is called latitude effect.

Explanation

Presence of such an effect indicates that the cosmic rays are changed particles. The earth magnetic field is from south to north. The earth's magnetic field at the equation is perpendicular to the direction of travel of charged cosmic ray particle. Therefore, it exert maximum deflection .They are deflected away from earth. The intensity of cosmic ray is, therefore, minimum at the equator, at poles, cosmic ray particles, move parallel to the earth's field. They, therefore, suffer minimum deflection. Hence the intensity of cosmic rays is maximum at the poles.

The minimum momentum P min at zenith is by

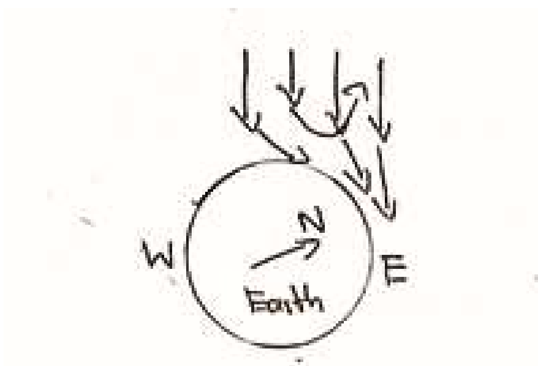
$$P\ min = 15\cos^4\lambda (Bev/c)$$

The East – West effect (Azimuth Effect)

It is found that the number of cosmic ray particle coming from the west is greater that these coming from the east. This effect is called east – west effect and is, maximum at equator. At the equator the number of particles coming from west is 14% more than the particles coming from east. This phenomenon gave an evidence of the fact that cosmic rays are composed predominantly of positively charged particles.

Explanation;

The charged particles approaching the earth's atmosphere deflected by the earth's magnetic field in perpendicular to the magnetic field and deflected towards the east by earth's magnetic field and thus appear to come from the west.

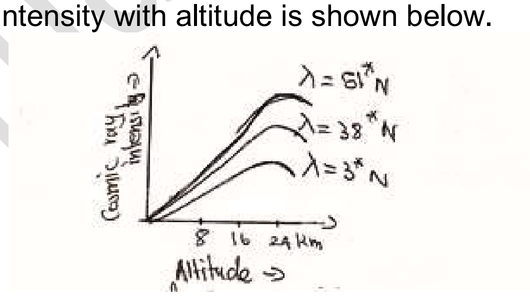


If 1 w and 1 E are the intensities of cosmic rays coming from the west and east respectively, then the east – west asymmetry is defined as

$$\frac{I_W - I_E}{[(I_W + I_E)/2]}$$

Altitude Effect

The variation of intensity of cosmic rays with altitude is called altitude effect. The variation of cosmic ray intensity with altitude is shown below.



It is observed that the intensity rises slowly upto height of about 8 km, after which the rise becomes fast upto about 19 to 24 km. At heights above 24 km, the intensity starts decreasing gradually. The experiments were conducted at 3 ^{0}, 38^0 and 51^0 N and the result are similar.

The maxima of intensity is not at the top of the atmosphere due to interaction with nuclei of atmospheric gases. Thus both primary and secondary rays are present in abundance at the height. With decreases of altitude the absorption increases and therefore, intensity falls.

Longitude effect:

The variation of intensity of cosmic rays with longitude is called the longitude effect. The intensity of cosmic rays also depends upon the longitude of the point of observation. It is called longitude effect. The intensity of cosmic radiation along the equator varies at different longitudes. This equation variation is attributed to the fast that the earth's magnetic field is not symmetric about the its axis.

Primary cosmic rays;

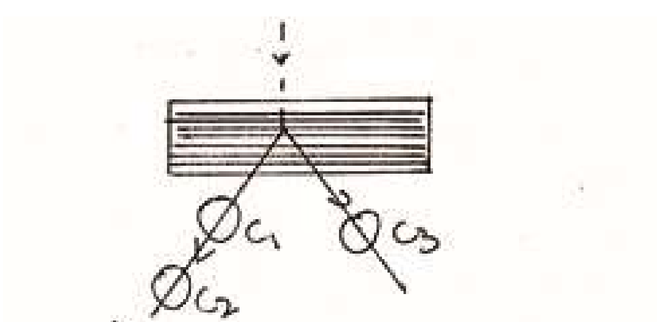
The cosmic rays which are just entering out earth's atmosphere from outer space are called primary cosmic rays. Primary cosmic rays consists mainly of positively charged atomic nuclei with z upto 40. About 90% arprobns 990 helium nuclei and the remaining heavy nuclei. The energies of primary cosmic rays range from 1 mev to 10^4 MeV

Secondary cosmic rays;

When primary cosmic rays interact with the nuclei of atmospheric gases, secondary cosmic rays are produced. Below an altitude of 20 km, all cosmic radiation is sufficient energy and decay into lighter particles; u – reasons, electrons, positions, neutrinos and photons. All such particles constitute the secondary cosmic rays. At sea level the secondary cosmic rays contain nearly 7070 u – masons, 29% electron – position pairs and 190 heavy particles.

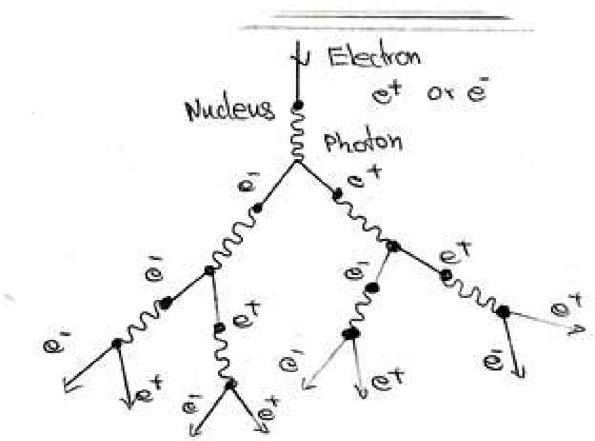
Cosmic ray showers;

A group of cosmic ray particles is called the cosmic ray shower, a lead plate is used to produce the cosmic ray shower and it is shown in the figure.



Cascade theory of showers;

Shower production involves two processes, viz, radioactive collision and pair production. A high energy electron (or position), present in cosmic rays, loses energy, when it encounters the atomic nuclei in earth atmosphere. The energy appears as high energy photon. The photon intervals with the electric fields of an atomic nuclear and is completely observed, resulting in the production of an electron – position pair. The energy required for a pair production is more than 1 MeV. The electron and position so produced have sufficient energy to produce more photons an interaction with nuclei. These photons are further



Pair production;

The conversion of a photon into an electron and a position is called pair production. The electric charge is conserved, is since the electron and position have charges of equal magnitude and opposite sign, the energy if the photon provides

(i) The rest energy of the electron ($m_o c^2$).
(ii) The rest energy of the position ($m_o c^2$).
(iii) The K.E of the electron (E^-) and
(iv) The K.E of the position (E^+)

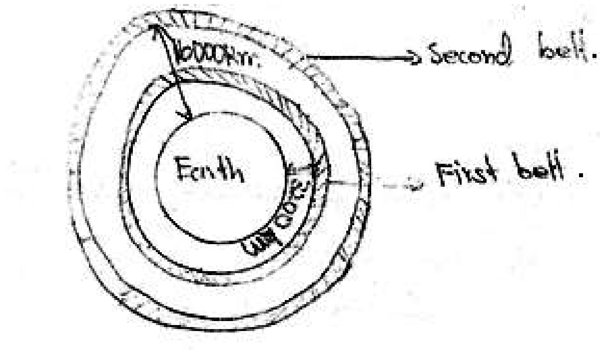
If hv is the energy content of the radiation, then

Annihilation of muffer;

The converse of the materialization of energy is the annihilation of matter. When a position combines with an electron both disappear producing two quant of y – rays;

[$e^+e^- \rightarrow 2y$]. This process is called annihilation of matter.

There are two strong radiation belts above 300km. They are called as van Allen belts. These belts are formed around the earth except at magnetic poles, at heights of 3200km and 1600km above the equator. Each belts contains two localized zones.



Inner zone:

It consists of photons of high energy of the order of 100 mev and electrons of low

Energy of the order of 1 mev

Duter zone:

It is less intense than the inner zone and consists of only low energy electrons, The energy being of the order 0.1 MeV.

The van Allen belts consists of high energy protons and electrons originating from the sum and cosmic rays that have been captured by the earth's magnetic fields. The existence of such a belt proved beyond doubt that high intensity particles are trapped by the earth's magnetic fields.

Origin of cosmic rays;

There are many theories for the origin of cosmic rays.

Explosion theory

Lemaitre, regener and others have suggested that this universe exploded, forming the galaxies which are still running away from each other. During the explosion, a fantastically great amount of radiation was formed, protons and other nuclei were shot and in all direction with all energies and in sufficient numbers. The cosmic rays are simply the debits, the dust of the explosion.

Origin from sun;

The sun may be the source of least some of the cosmic rays. According to it, at the times of solar activity violent exuptions occur and ionized gases shoot and out from the sun. Thus some of the protons in the sun acquire high energies and thrown out into interplanetary space.

Origin from cosmic ray stars;

Another view is that the cosmic rays come from the so called cosmic ray starts

Which are more active that the sun .Our galaxy has about 10^{11} stars including double stars, variable stars, and super noun, noun, all these may be the possible origins of cosmic rays.

The current view of the origin of cosmic rays is that the sun emits low energy cosmic rays while high energy cosmic rays are emitted by cosmic ray stars within are galaxy.

Elementary particles:
Classification

The classification of elementary particles can be make in the basic of the following.

1. Lighter particles:

It is also called as leptons.
Ex. Electron, neutrino, muon, etc.

2. Middle group of particles;

Like pions (π – masons), k – masons, etc.

3. Heavier particles;

Ex; a) Baryons b) hadrons

(i) Protons and neutrons are called as nucleons or baryons.

(ii) The baryons and masons are known as hadrons.

The classification is given below.

Elementary particles		
Light particles	**Middle group of particles**	**Heavier particles.**

Leptons and their properties

(i) Leptons are the lighter particles.

Example; electron, neutrino, muon , etc.

Properties:

Particle	Charge	Spin	Anti – particle
Electron	Negative (- 1.6$\times 10^{-19}$)	$\pm\frac{1}{2}$h	Position
Neutrino		$\pm\frac{1}{2}$h	Anti –neutrino
Muon	+ve, negative ,neutral	$\pm\frac{1}{2}$h	Anti –muon

Muons:

There are three types of muons.

(i) Positive muon.

Hadrons

Hadron, are baryons and mesons.

Baryons:
Baryons are protons and neutrons.

Properties of baryons;

Particle	Rest mass	Spin	Anti - particular
Protons	Positive(- 1.6 × 10^{-19})	$\pm\frac{1}{2}$h	Anti – protons
Neutrons	No charge	$\pm\frac{1}{2}$h	Anti – neutrons

Mesons;
Mesons are middle group of particles. The mass of meson is more than that of electrons and less than that of protons.

Types of meson.
(i) Π – mesons
(ii) K – mesons
(iii) D – mesons

a) π- mesons - π^t mesons ,π^-mesons , π^omesons.
b) K – mesons - k^tmesons , K^-mesons , K^omesons.
c) D- mesons - D^t mesons ,D^-mesons , D^omesons.

Particle interaction; (fundamental interaction)
They are also called as fundamental interaction. They are four types.
(i) Gravitational interaction
(ii) Electromagnetic interaction
(iii) Strong nuclear interaction
(iv) Weak nuclear interaction

Gravitational interaction;
The interaction between one mass and another mass is called the quantitation interaction. The interaction
Where, G – gravity constant, n_1, m2 – the masses, r – distance between two masses.

Examples;
(i) The interaction between earth and moon
(ii) The interaction between sun and earth

The range of interaction is carrier particle is gravitation. This is the weakest force compared to all other forces.

Electromagnetic interaction;
The interaction between radiation (photon) and charged particle is called electromagnetic interaction.
Ex;
Photo electric effect, Compton Effect. The range is a carrier particle is photon.

Strong nuclear interaction.
The interaction between nucleons (photons& neutrons) is called strong nuclear interaction.
Ex;

Proton – proton interaction, proton – neutron interaction, neutron – neutron interaction. The range is 10^{-15}m.carrier particle is gluon.

Weak nuclear interaction;

The interaction between mouns and neutrinos is called weak nuclear interaction.

The equation are given below.

(i) $U^{+}+y \rightarrow \pi^{+}$

(ii) $U^{-} +y \rightarrow \pi^{-}$

Nuclear interactions but not in weak interaction. Let P be the parity operator and it be the humiltanian operator then the commutated [PH] = 0. This express the parity conservation. In a reactionintial parity = final parity.

Conclusion:

A nuclear interaction on nuclear decay proceeds when the above conservation laws are obeyed. The decay or reaction is kinematic ally not possible if objected to by any these conservation laws.

Ruarks:

Ruarksare found in protons, neutrons and mesons

Types of quarks:

(i) Up quark (U)
(ii) Down quark (d)
(iii) Top quark (t)
(iv) Bottom quark (b)
(v) Charm quark (c)
(vi) Strange quark (s)

quark	Symbol	Charge
Up	U	$+\frac{2}{3}$
Down	d	$\frac{1}{3}$
Top	t	$+\frac{2}{3}$
Bottom	b	$-\frac{1}{3}$
Charm	C	$+\frac{2}{3}$
Strange	S	$-\frac{1}{3}$

Quark model in a proton;

The diagram for mode of proton is given below.

U – up quark, d – down quark,

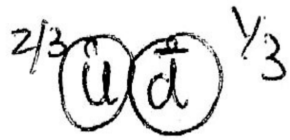
The proton consists of two up quarks and one down quarks.

The total charge = $\frac{2}{3}+\frac{2}{3}-\frac{1}{3}$ = 1

Hence the proton has one unit of charge.

Quark model for a neutron;

The diagram for the quark model for neutron is given below.



In the above diagram, u – up quark, d – down quark.

The neutron consists of one up quark and two down quark.

Total charge = $\frac{2}{3}$ - $\frac{1}{3}$- $\frac{1}{3}$ = 0

Hence the neutron has no charge.

Quark model for a π – meson.

The diagram for the quark model for a π meson is given below.

In the above diagram u – upto quark, d – down quark

The π – meson consists of on up quark and one down quark.

Total charge = $\frac{2}{3}$ + $\frac{1}{3}$ = 1

Hence the π meson has one unit of charge.

Conservation laws;

There are two types.

(i) Conservation law of leptons;

Lepton number remains constant in a nuclear reaction.

Ex;

Consider a nuclear equation as

n→ p + e-+$\bar{\gamma}$

in left hand side;

Lepton number for neutron = 0

in R.H.S

Lepton number for proton = 0

Lepton number for electron (e^1) = 1

Lepton number for antineutrino = - 1

0 = 0 + 1 – 1 = 0

∴L.H.S = R.H.S

∴ Lepton number remains constant.

(ii) Conservation law of baryons;

Baryons number remains constant in a nuclear reaction.

Ex.

Consider the nuclear equation as

n→ p + e-+$\bar{\gamma}$

L.H.S; baryons number for neutron = 1

R.H.S; baryons number for proton = 1

Baryon number for electron = 0

Baryons number remains constant.

Strangeness conservation;

Certain particles like – k – meson,λ – meson and Σ particles are produced by strong interaction but decay through weak interaction. These are called strange particles.

A new quantum number strangess is assigned to such particles.

For k – meson , s = + 1

For λ & Σ, s = - 1

For x particle S = - 2

For omega particles s = - 3

Their antiparticles have opposite sign. For π mesons and lepton, S= 0. The conservation law for strangeness is in the process governed by electromagnetic and strong interactions, the total strangeness remains constant or changes by one unit.

Isopin conservation law;

Isopin is conserved in strong interaction but not in electromagnetic interactions. Hyper chance y = B+S is conserved in strong interactions. But violated in weak interactions.

Parity conservation;

If an event occurs and its mirror image (involving anti private) also occurs in nature the event.

Example

$\mathbf{92u^{238}90Th^{234} + 2He^{4}}$

(α – ray)

(iii) In beta decay (beta ray emission),the atomic number is increased by 1 and mass

Number will not change.

Ex; $82\mathbf{pb}^{212} \rightarrow \mathbf{83Bi}^{212} + \boldsymbol{\beta} - \mathbf{ra}$

(iv) In gamma decay. There is no change in atomic number and mass number.

$38Sr^{97*}$→$38Sr^{97}$+ 8 – ray.

Sr* is the unstable nucleus.

PACKING FRACTION:

It is defined as the ratio of mass defect and mass number. It is also called as the mass defect per nuclear.

∴Packing fraction = $\frac{\Delta m}{A}$=P.F

Where, Δ**m** →mass defect.

A →Mass number.

Where, z → **atomic number**

m_p →Mass of a proton.

m_n – Mass of a neutron

M – Mass of nucleus.

Packing fraction (PF) is a also written as

$$\text{P.F} = \frac{Actual\ isotopic\ mass - mass\ number}{mass\ number}$$

P.F = $\frac{M-A}{A}$

If packing fraction is low, binding energy is high and hence nuclear stability is more.

Neutron participating in nuclear fission must be slow neutrons or thermal neutrons. The fast neutrons are slowed by materials called moderators. Heavy water (D_2D), graphite and beryllium are used as moderators. The reactor generates considerable amount of head due to fissions and the Heat is removed by cooling fluids known as coolants. The coolant should no react with neutrons. A good coolant should have high specific heat capacity and high thermal conductivity. Gases like helium, nitrogen and air or liquid metals such as sodium or mercury are used as coolants.