Chapter -8(B,C)

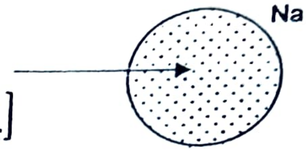
Q.1 (a) Proton – electron hypothesis.

(b) Reasons for its failure.

Ans. (a) <u>Proton-electron hypothesis:</u> Nucleus consists of protons and electrons.

Example:

$$\left.\begin{array}{r} 23\ Protons \\ 12\ electrons \end{array}\right]$$



Total Charge = 23(+e) +12 (-e)

= 11(+e)

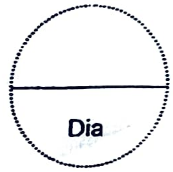
(b) Reasons for failure.

(1) <u>Energy:</u> Uncertainty in position,

Δx = Dia, $\Delta P \to ?$

$\Delta x . \Delta p$ = constant

$\Delta KE = \frac{(\Delta p)^2}{2m}$



20 Mev < $KE_{theoretical}$ < 200 Mev

But $K_{practical}$ = 2 to 3 Mev

(2) <u>Nuclear Spin:</u>

Theoretical Values of nuclear spin ≠ Practical value of nuclear spin

$(\text{Total spin})_{theoretical}$ = (Spin of proton) (No. of protons) + (spin of e^-) (No. of e^-) ≠ $(\text{Total spin})_{practical}$.

(3) <u>Magnetic moment:</u>

Theoretical values of magnetic moment ≠ Practical value of magnetic moment

(4) The presence of a few electrons inside the nucleus and others revolving in orbit around the nucleus show dual role of electrons in atomic structure, which is difficult to visualize.

+2 / Unit 8B / Q1 Proton Electron Hypothesis

Q.2 Find ratio of R_{max} to R_{min}?

Where, R_{max} → radius of largest nuclei in periodic table.

R_{min} → radius of smallest nuclei in periodic table.

+2 / Unit 8B / Q2 Radius of nucleus

Ans. Volume ∝ no. of nucleons

$$\frac{4}{3}\pi R^3 \propto A$$

$$\boxed{R \propto A^{1/3}}$$

$$\boxed{R = R_o A^{1/3}}$$

$R = R_o$ when A = 1 for hydrogen

$R = R_o = 1.1 \times 10^{-15}$ m for hydrogen.

$$\frac{R_{max}}{R_{min}} = \left(\frac{A_{max}}{A_{min}}\right)^{1/3} = \left(\frac{300}{1}\right)^{1/3} = \frac{6.5}{1} \simeq (7:1)$$

Q.3 Find ratio of nuclear density to water density?

+2 / Unit 8B / Q3 Nuclear Density

Ans. $\rho_{nuclear}$ --> ? $\rho_{water} = 10^3$ kg / m^3

$$\rho_{nuclear} = \frac{1.67 \times 10^{-27}}{\frac{4}{3}\pi\left(1.1 \times 10^{-15}\right)^3} = 2.99 \times 10^{17}$$

$$\frac{\rho_{nuclear}}{\rho_{water}} = 10^{14}$$

Q.4 Explain

(a) Isotopes. (b) Isobars (c) Isotones with examples.

Ans. (a) Isotopes:- Same no. of protons, different nucleons.

Ex → $_1H^1$, $_1H^2$, $_1H^3$.

(b) Isobars:- Same nucleons, different protons.

Ex → $_{11}Na^{22}$, $_{10}Ne^{22}$

(c) Isotones:- Same neutrons

Ex → $_{17}Cl^{37}$, $_{19}K^{39}$

$$\downarrow \qquad\qquad \downarrow$$

$$\begin{bmatrix} Neutrons \\ = 37 - 17 \\ = 20 \end{bmatrix} \quad \begin{bmatrix} Neutrons \\ = 39 - 19 \\ = 20 \end{bmatrix}$$

+2 / Unit 8B / Q4 Isotopes Isobars and Isostones

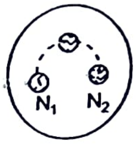
Q.5 **(a) What causes two nucleons to attract each other?**

(b) Characteristics of nuclear force.

Ans. (a) Source of nuclear force was explained by H. Yukawa in 1936 on the basis of "particle exchange theory".

Two badminton players stay together because they exchange a particle "shuttle"

Two nucleons stay together because they exchange "π- meson".



(b) Characteristics:

1. **Independent of charge:** Force between a proton and proton is same as that between a proton & neutron.

2. **Strongest:-** $\frac{F_{Nuc}}{F_{electric}} = 100$, $\frac{F_{Nuc}}{F_{grav}} = 10^{38}$

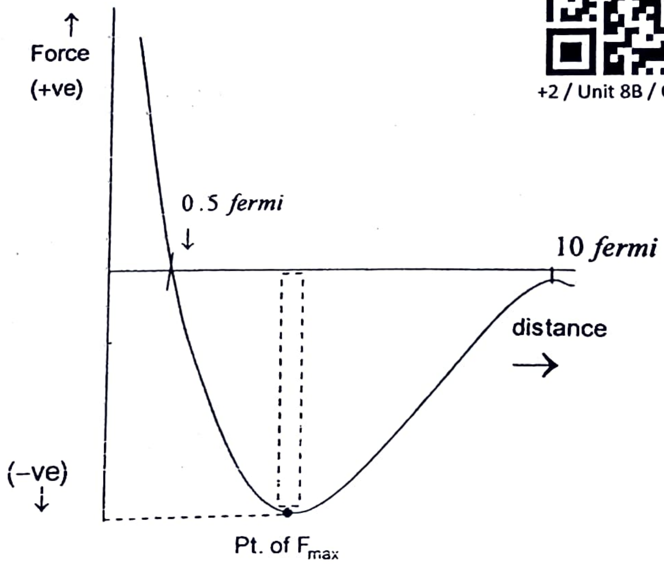
3. **Short range:** Range is of order of fermi → 10^{-15} m.

4. (a) When distance between two nucleons is more than 10 fermi, force is attractive & small.

   (b) For distance less than 0.5 fermi, force is repulsive.

   (c) Nuclear force does not obey inverse square law.

+2 / Unit 8B / Q5 Nuclear Force



5. Depends on spin

6. Non-central.

Q.6 (a) What is B.E.? B.E. formula?
(b) B.E/nucleon graph and its significance?
(c) Explain "fission" and "fusion" using B.E/nucleon graph?

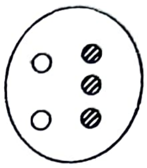
Ans. (a) B.E. → Work required to be done to separate the nucleon to ∞.

B.E = $(\Delta m)\,C^2$

↓

mass defect = $[z.m_p + (A-z), M_n - M_{nuclei}]$

B. Energy = $\{[z.m_p + (A-z), M_n - M_{nuclei}]C^2\}$



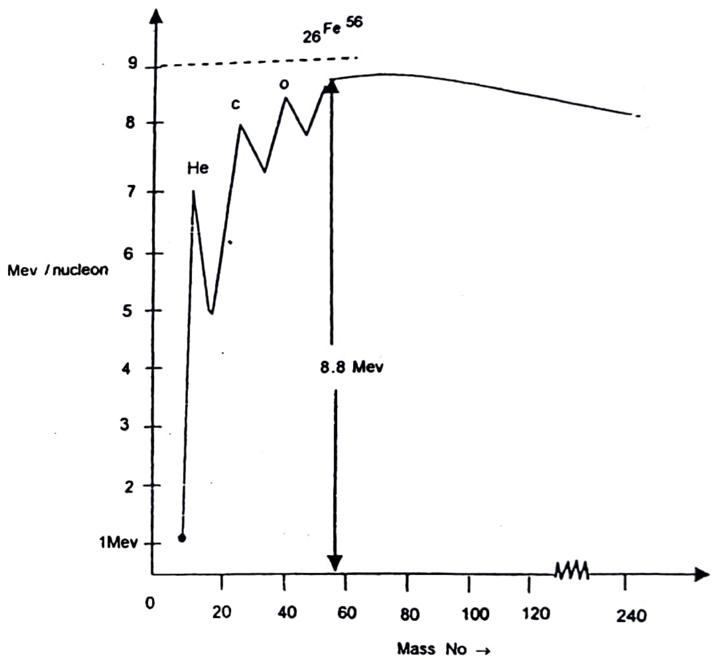
$_{Z}X^{A}$ $_{2}X^{5}$

No. of nucleons → A
No. of protons → Z
No. of neutrons → A – Z

(b) B.E/nucleon graph $\frac{B.E}{nucleon} = \frac{Total B.E of\ nucleus}{no. of\ nucleons}$

Observations:

1. B.E/nucleon for small nuclei is low.
2. Peaks → He^4, C^{12}, O^{16}
3. Max. at $_{26}Fe^{56}$ is 8.8
4. For Mass no. > 56 as size increases, B.E / nucleon decreases.



Significance:- Light nuclei He, C etc are stable because their B.E/nucleon is of 7- 8 MeV/nucleon. Very heavy nuclei like $_{92}U^{238}$ are unstable as B. E/ nucleon is less.

(c) Fission: Process in which heavy nuclei (eg . U) breaks into smaller nuclei which results in release of energy.

$$_{92}U^{235} + {}_{0}n^{1} \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\ {}_{0}n^{1} + Q$$

Heavy nuclei which is having less B.E/nucleon splits to give smaller nuclei having more B.E/nucleon Energy difference appears as "Energy fission" process.

Fusion: Very light nuclei (e.g H) combine to give nuclei (He) and results in release of energy.

$$_{1}H^{2} + {}_{1}H^{2} \rightarrow {}_{2}He^{3} + {}_{0}n^{1} + 3.27\ MeV$$

+2 / Unit 8B / Q6 Binding energy significance Fission and Fussion

Q.7 Prove no. of nucleons decay exponentially in radioactivity?

Ans. Let the no. of nuclei at t = o is $= N_o$

Let the no. of nuclei at any time = N

(Death Rate) ∝ (Population)

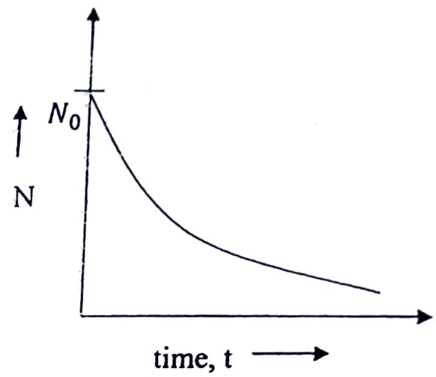
$$\frac{dN}{dt} \propto N$$

$$= \lambda . N$$

↓

Decay constant

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



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

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

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

Integrate both sides.

$$\int \frac{dN}{N} = -\lambda \int_{t=o} dt \qquad \left(\int \frac{dx}{x} = \log_e x\right)$$

$$|\log_e N| \Big|_{N=N_o}^{N=N} = -\lambda \, |t| \,_{t=0}^{t=t}$$

+2 / Unit 8B / Q7 Nuclear Decay Exponential Function

$$\log_e N - \log_e N_0 = -\lambda (t - 0)$$

$$\log_e\left(\frac{N}{N_o}\right) = -\lambda(t) \qquad \begin{pmatrix} \log_e x = y \\ x = e^y \end{pmatrix}$$

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

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

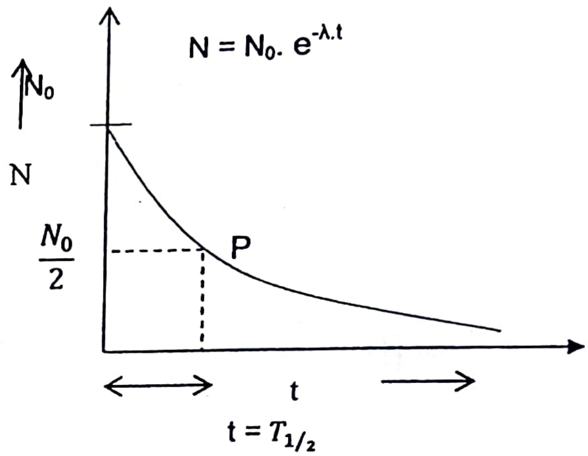
Q.8 **(a) What is "half-life"? Find relation b/w "half life" and "decay constant"?**
(b) Plot "Activity" v/s time graph?
(c) Units of Radioactivity.

Ans. (a) "**Half Life**" :

Half life of a nuclei is defined as time taken during which the no. of nuclei reduce to half of original.

Relation $T_{1/2}$ and λ

$N = N_0 . e^{-\lambda t}$



At point P in graph. $N = \frac{N_0}{2}$, $t = T_{1/2}$

$\frac{N_0}{2} = N_0 \, e^{-\lambda T_{1/2}}$

$\frac{1}{2} = \frac{1}{e^{\lambda}} T_{1/2}$

$e^{\lambda T_{1/2}} = 2$

Take log on two sides

$log_e \, e^{\lambda T_{1/2}} = log_e 2$

$\lambda \, T_{1/2} = log_e 2$

$$T_{1/2} = \frac{0.693}{\lambda}$$

(b) Death rate ∝ N

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

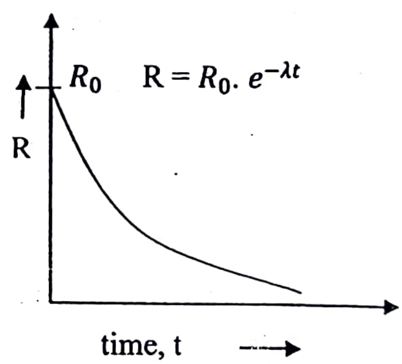
$= (\lambda \, N_0) \, e^{-\lambda t}$

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

↓

Activity at any time

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



Where R_0 = Initial Activity

(c) Units of radioactivity

(i) Curie (Ci) = 3.7×10^{10} decay /sec

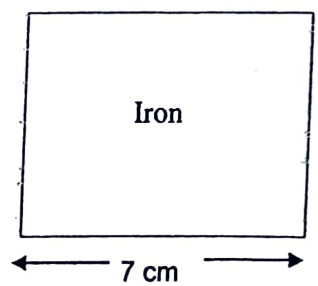
(ii) Becquerel (Bq) = 1 decay / sec

(iii) Rutherford (Rd) = 10^6 decays /sec

+2 / Unit 8B / Q8 Half life Radioactivity units of Radioavtivity

Q.9 Compare α, β and Y radiations.

Ans.

	<u>α</u>	<u>β</u>	<u>Y</u>
1.	Charge = +2e	Charge = - e	No Charge. It is radiation.
2.	Mass = 4 x (mass of one nucleon)	Mass = 9.1×10^{-31}kg.	Rest mass of a photon is "Zero"
3.	1.4×10^7 m/s < vel< 2.1×10^7 m/s $\left(\frac{1}{10}\text{speed of light}\right)$	Speed 33% -99% of 3×10^8 m/sec	Speed = 3×10^8 m/sec
4.	Penetrating Power Small  AL 0.02 mm of Alumi	Medium  5 mm of Aluminium	Large  Iron 7 cm
5.	Ionising Power Large	$\frac{1}{100}$(Ionising Power of α)	Small Ionising Power.
6.	Range 3 to 8cm	Range – 7m	Range – Very large distances
7.	Deflection by Electric and Magnetic field.	Deflection by Electric and Magnetic field.	No deflection by Electric or Magnetic field.

+2 / Unit 8B / Q9 Comparison of Alpha Beta Gamma Radiations

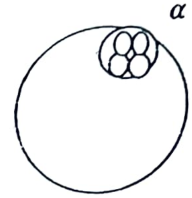
+2 / Unit 8B / Q10 Alpha Decay

Q.10 **Discuss**

(a) α – decay
(b) β – decay
(c) γ – decay

Ans. **<u>α – decay:-</u>** **<u>Definition:-</u>** It is phenomena of emission of an α – particle from nucleus.

α – particle

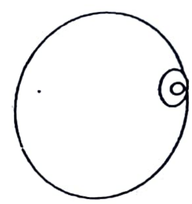


<u>Reaction:-</u>

$${}_{z}X^{A} \rightarrow {}_{z-2}Y^{A-4} + {}_{2}He^{4} + \text{energy}$$

<u>Law of Conservation of Momentum:-</u>

$$\boxed{M_Y V_Y = M_\alpha V_\alpha} \quad \text{———— (1)}$$

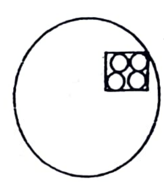


$$K.E = \frac{1}{2} m_Y \, V Y^2 = \frac{p^2}{2m_Y}$$

$$K.E_\alpha = \frac{1}{2} m_\alpha V_\alpha^2 = \frac{p^2}{2m_\alpha}$$

<u>Process:-</u>

(1) α – particle exists in nucleus as separate entity.



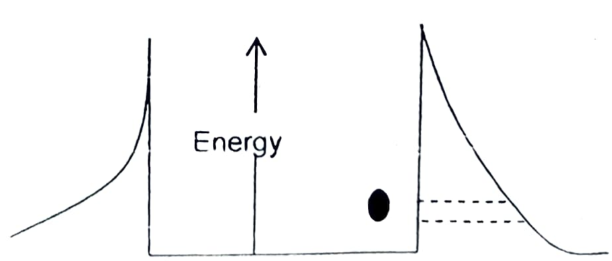
(2) α – particle moves inside at speed = 10^7 m/sec

Dia. of nucleus $= 10^{-14}$m

No. of collision with the wall / sec $= \dfrac{10^7 \, m/\sec}{10^{-14} \, m} = 10^{21}$ 1/sec

Probability of escape is small but finite No. of collisions are very large. So, it results in "finite chances" of escape.

(3) Energy is not sufficient to cross the barrier but still the α – particle can "tunnel" .



β- decay

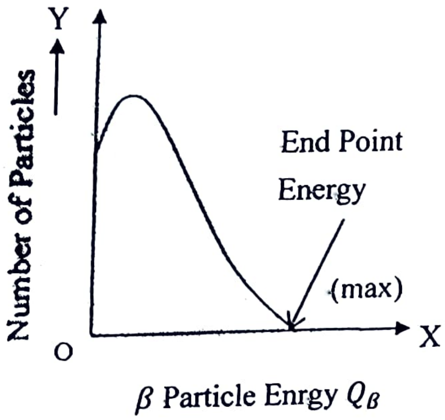
Definition:- It is phenomena of emission of an electron from nucleus.

Reaction:- $_{z}X^{A} \rightarrow {}_{z+1}Y^{A} + {}_{-1}e^{0} + \text{Energy}$

Process:- Energy graph

- Most particles carried small energy.
- Few β – particles carry high energy
- Energy graph is continuous.
-

+2 / Unit 8B / Q10 Beta Decay



Neutrino hypothesis:-

As per theory given above, Law of conservation of energy and angular momentum was violated. Pauli came out with a theory that one more particle should be there in given equation to satisfy law of conservation of energy and angular momentum.

$$_{z}X^{A} \rightarrow {}_{z+1}Y^{A} + {}_{-1}e^{0} + \nu + \text{Energy}$$

↓ (ν) neutrino

(c) Y- decay

Definition:- It is phenomena of emission of a photon of energy.

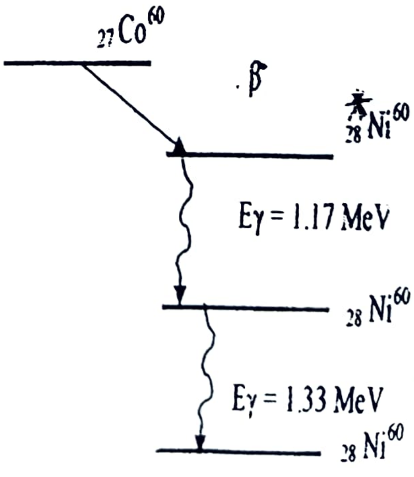
Reaction: $^{*}_{z}X^{A} \rightarrow {}_{z}X^{A} + \gamma$

Process

i) $_{27}Co^{60} \rightarrow {}_{28}{}^{*}Ni^{60} + {}_{-1}\beta^{0} + \bar{\nu}$

ii) $_{28}{}^{*}Ni^{60} \rightarrow {}_{28}Ni^{60} +$ ▨ Y – ray photon

↑ 1.17 Mev



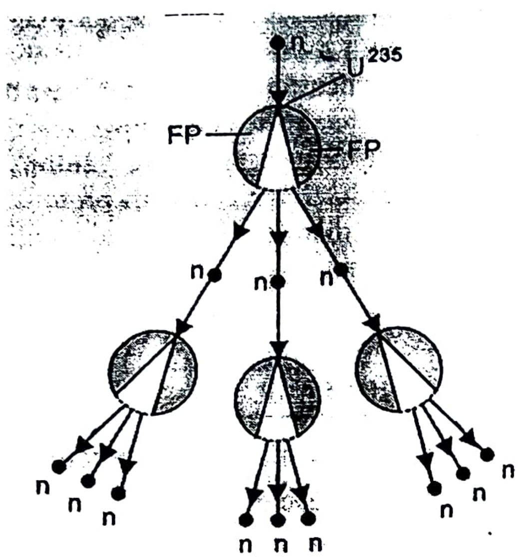
+2 / Unit 8B / Q10 Gamma Decay

Q.11 Nuclear fission? Chain Reaction?

Necessary conditions for maintaining chain reaction.

Ans. Nuclear fission is the phenomenon of splitting of a heavy nucleus (Usually A > 230) into – two or more lighter nuclei.

$$_{92}U^{235} + {}_0n^1 \rightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3{}_0n^1 + \text{Energy}$$



+2 / Unit 8B / Q11 Nuclear Fission and Chain reaction

Nuclear chain Reaction:-

The three secondary neutrons produced in the fission of one $_{92}U^{235}$ bring about fission of more $_{92}U^{235}$ nuclei and so on. Such continuous reaction is called nuclear chain reaction.

Necessary condition for chain reaction:-

The chain reaction once started will remain steady, accelerate or retard depending upon, the" neutron Reproduction Factor(K).

$$K = \frac{\text{Rate of production of neutrons}}{\text{Rate of loss of neutrons}}$$

If K=1, The operation of the reactor is said to be 'critical', which is what we wish it be for steady power generation.

If K > 1, The chain reaction accelerates resulting in an explosion. The size of the material in this case is 'super critical', this is how an atom bomb works.

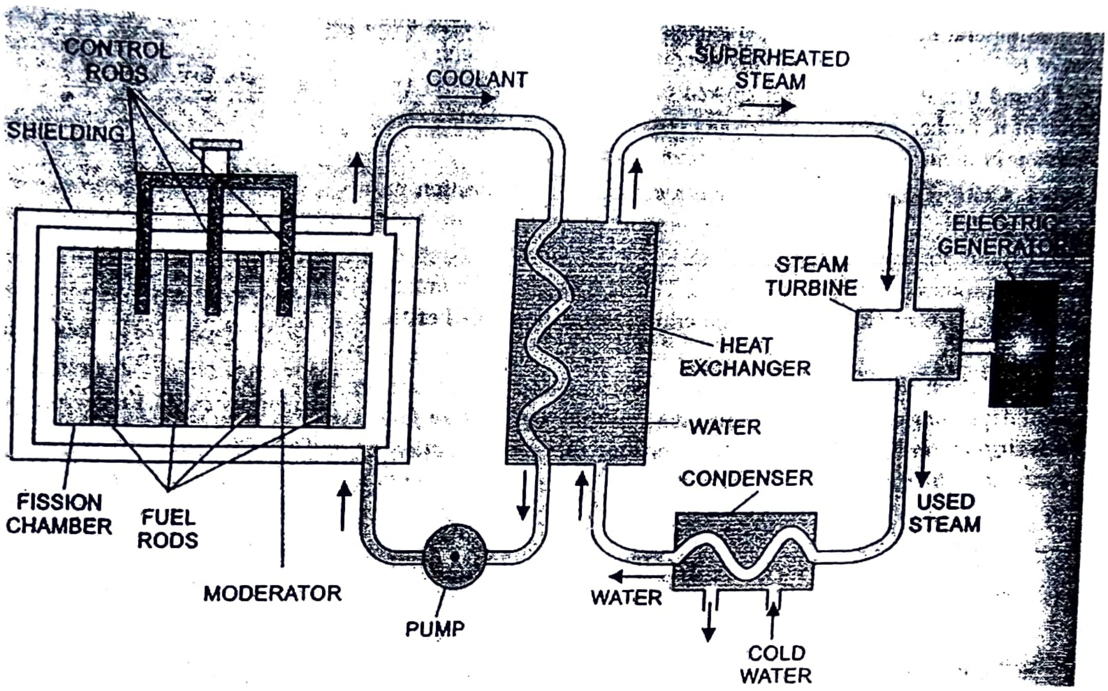
If K< 1, The chain reaction gradually comes to halt. The size of material used is 'sub critical',

Thus $\boxed{K = 1}$ is the required condition for maintaining chain reaction

Q.12 Diagram of nuclear reactor? Discuss functions of each of it's main component.

Ans. A nuclear reactor is based upon **'controlled nuclear reaction:-**

Diagram:-



Some main Components:

1. **Nuclear Fuel :-** Commonly used fuels in a nuclear reactor are U^{233}, U^{235}, Pu^{239}

2. **Moderator:-** Its function is to slow down the fast moving secondary neutrons produced during the fission, material used D_2O.

3. **Control Rods:-** They have the ability to capture the slow neutrons.

4. **Coolant:-** A substance which is used to remove the heat produced and transfer It from the core of the nuclear reactor to the surroundings, is called Coolant.

5. **Shielding:-** Concrete walls, 2 to 2.5 m thick to prevent radiations from penetrating.

+2 / Unit 8B / Q12 Main Components of Nuclear reactor

Q13. (a) Explain phenomenon of nuclear fusion, giving examples.
(b) Give comparison of "Fission" and Fusion reaction.

Ans: (a) Nuclear fusion is the phenomenon of two light nuclei fusing to form a larger Nucleus.

Examples:- 1) ${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He$ + n + 3.27 MeV

2) ${}^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{1}H + {}^{1}_{1}H$ + 4.03 MeV

(b) Comparison of "Fission" and "Fusion".

1. Both, nuclear fission and fusion are the source of tremendous energy.

2. **Energy per reaction:** In both the reactions large amount of energy is produced. But in Comparison energy produced in fission reaction is more than that of fusion reaction.

3. **Energy/mass**: Energy produced per unit mass is greater in fusion reaction than fission reaction.

4. Nuclear fission may precedes nuclear fusion because for fusion suitable energy is to be made available by raising temperature of order of 10^7 K. (Which is generated by nuclear fission).

5. In both the processes, certain mass (Δm) disappears, which appear in the form of energy as per Einstein equation E = (Δm) c^2

6. **End Product:** The end product of nuclear fission reaction is radioactive and needs careful disposal. But the end products of fusion reaction are harmless and disposed off easily.

7. **Control:** Energy produced during fission reaction can be controlled easily but comparatively difficult in fusion reaction.

+2 / Unit 8B / Q13 Nuclear Fusion comparison of Fission and Fusion

Q14. Give varius laws of Radioactive Disintegration does not depend upon external factors like temperature, pressure etc.

Ans: 1. Radioactivity is a spontaneous process which does not depend upon external factors like temperature, pressure etc.

2. During disintegration of an atom, either α - particle or β- particle is emitted. Both of these are never emitted simultaneously.

3. Emission of α – particle results a new atom whose atomic number is reduced by two & mass number is reduced by four,

$${}_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_{2}He^{4} + \text{Energy.}$$

4. Emission of β particle results a new atom whose atomic number is raised by one, without any change in its mass number

$${}_{90}Th^{234} \rightarrow {}_{91}Pa^{234} + \; - e^{0} + \text{Energy.}$$

5. The number of atoms disintegrated per second at any instant is directly proportional to the number of radioactive active atoms actually present in the sample at that instant.

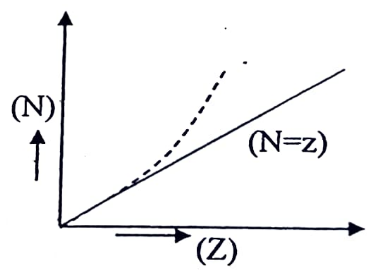
+2 / Unit 8B / Q14 Laws of radioactive Disintegration

Q15. Name the various factors on which nuclear stability depends?

Ans: 1. **Binding Energy per nucleon:** Higher the B.E/ nucleon more stable is the nucleus.

2. Stability of nucleus is also determined by its neutron to proton ratio.

$\frac{N}{Z} \geq 1$ (except hydrogen)



3. The stability of nucleus also depends on even or odd numbers of protons & neutrons.

EE > EO >OO.

$$\begin{pmatrix} \text{EE} \rightarrow \text{Even Even} \\ \text{EO} \rightarrow \text{Even odd} \\ \text{EO} \rightarrow \text{odd odd.} \end{pmatrix}$$

+2 / Unit 8B / Q15 Factors on which nuclear stability depends