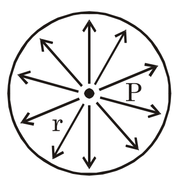
PHOTON

- Max plank said light is mode up of discrete packets of energy called 'Photon' according to his quantum theory.
- Energy of photon, E = hv, where h = Plank's constant = 6.63×10^{-34} Fs and v = frequency of light used.
- Effective mode of photon, $m = \frac{E}{C^2}$; $m \propto \frac{1}{\lambda}$. So effective mass of violet light is more then effective mass of red light photon.
- Rest mass of a photon is zero.
- Linear momentum of photon

$$P = \frac{E}{C} = \frac{hv}{c} = \frac{h}{\lambda}$$

INTENSITY OF LIGHT

$$\text{Intensity} = \frac{\text{Energy}}{\text{time} \times \text{Area}}$$

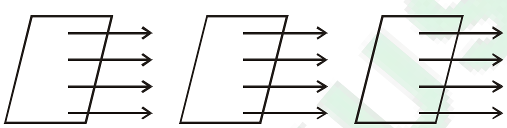


Point source
$I = P\ 4\pi r^2$
where P = power of source
Infinite linear source

$$I = \frac{P}{2\pi r\ell}$$

Infinite planar source

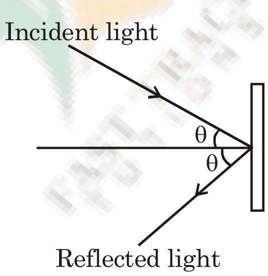
I = constant (independent of distance)
$I \propto P$



$I = \frac{Nhv}{At}$, $n = \frac{N}{t} = \frac{I \times A}{hv} =$
No of photons incident per second

Force exerted by light on a surface

$F = \frac{IA}{C}(1+r)\cos\theta$, where r = reflectivity



Radiation Pressure (P)

$$P = \frac{F}{A} = \frac{I}{C}(1+r)\cos^2\theta$$

Photo Electric Effect (PEE)

This experiment shows particle nature of light.

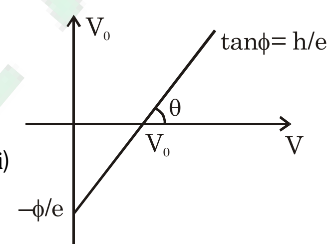
Electrons are emitted a metal surface when light is incident upon it only when $v \geq v_0$ (Threshold frequency) and P.E.E. is independant of intensity of light. This is shown as ther is no time rag in emission of electron.

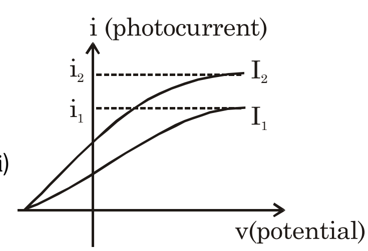
Einsten's Photoelectric Equation

$hv = \phi t\ KE_{max}$.
where ϕ = work function which depends on metal
KE_{max} = maximum KE that an e^- can have after emission.
$KE_{max} = eV_0$, where V_0 = stopping potential or cut of potential
So, $hv = \phi + eV_0$

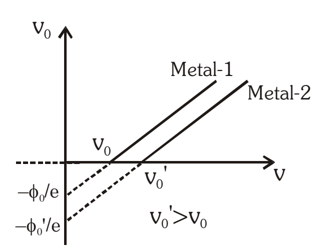
or $V_0 = \frac{hv}{e} - \frac{\phi}{e}$

Graphs of Photo Electric Effect

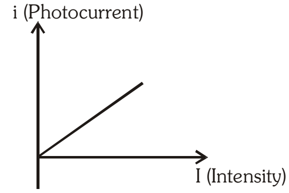
(i)


(ii)


i_1, i_2 = Saturation currents
$I_2 > I_1$ (v = same)

(iii)


(iv)



Quantum efficiency

Quantum efficiency =

$$\frac{\text{No. of electron emitted per second}}{\text{Total no. of photon incident per second}}$$

$$i = n\frac{IA\lambda}{hc} \text{ (Saturation current)}$$

Refer graph (iv)

Photocell : Works on PEE, Photocell light energy is converted into electrical energy.

Matter waves theory

Light has dual nature

Experiments like reflection, refraction, interference deffraction are explained only ont the basis of wave theory of light.

Experiments the PEE and crompton effect, pair production and positon axilation are explained on the basis of particle nature of light.

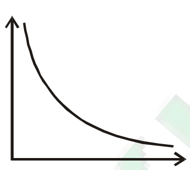
Atomic Structure

Various Models for structure of Atom

(i) Dalton's Theory

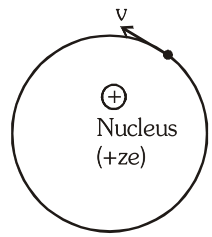
(a) Thomson Model

(b) Rutherford model



(Number of α-particles scattered at an angle θ)

Bohr atomic model



(i) Electron revolves circular orbit around nucleus

(ii) $mvr = \frac{nh}{2\pi}$

So electron has discrete angular momentum and is allowed to be present in certain fixed orbits only (called as stationary energy levels or shells.)

(iii) Electrons denot radiate energy when in shells but energy is radiated or aborbed when an electrons jumps to lower or higher orbit respectively.

Mathematical Analysis of Bohr's Theory

(i) $v = 2.2 \times 10^6\ 2/n$ m/s

(ii) $r = 0.53\ \frac{n^2}{z}$ Å

(iii) Total energy of electron in n^{th} orbit,

$$E_n = -13.6\frac{z^2}{n^2}\text{eV}$$

(iv) $T = \left(\frac{n^3}{z^2}\right)1.51 \times 10^{-16}\,\text{s}$

(v) $f = \left(\frac{z^2}{n^3}\right)6.6 \times 10^{15}\,\text{Hz}$

(vi) $\frac{1}{\lambda} = Rz^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$,

R_H = Rydberg constant = $\frac{1.097 \times 10^{-3}}{\text{Å}}$

(For stationary nucleus)

$R' = \frac{R_H}{1 + m/M}$ (If nuceus is not stationary)

i.e. mass of nucleus and revolving particle are comparable)

where m = mass of revolving particle

M = mass of nucleus

S.No.	Series Observed	Value of n_1	Values of n_2	Position in the Spectrum
1.	Lyman Series	1	2, 3, 4 ..... ∞	Ultra Violet
2.	Balmer Series	2	3, 4, 5 ..... ∞	Visible
3.	Paschen Series	3	4, 5, 6 ..... ∞	Infra-red
4.	Brackett Series	4	5, 6, 7 ..... ∞	Infra-red
5.	Pfund Series	5	6, 7, 8 ..... ∞	Infra-red

De Broglie Hypothesis

He said there wave nature of very particle just the light has dual nature.

$$\lambda_D = \frac{h}{p} = \frac{h}{\sqrt{2mK\sqrt{2}}},$$

where λ_D = De-Broglie wvaelength of any particle.

$\lambda_D = \dfrac{h}{\sqrt{2mqV}}$; if particle has charger and is accelerated by V

$$\lambda_{electron} = \frac{12.27}{\sqrt{V}}$$

$$\lambda_{Proton} = \frac{0.286}{\sqrt{V}} \text{Å}$$

$$\lambda_{Deutron} = \frac{0.202}{\sqrt{V}} \text{Å}$$

$$\lambda_{\alpha-Particle} = \frac{0.101}{\sqrt{V}} \text{Å}$$

Bohr's quantigation

$$mvr = \frac{nh}{2\pi}$$

Total emission spectral lines

From $n_1 = n$ to $n_2 = 1$ state $= \dfrac{n(n-1)}{2}$

From $n_1 = n$ to $n_2 = m$ state is $= \left(\dfrac{(n-m)(n-m+1)}{2}\right)$

$= {}^{n-m}C_2$

Excitation potential of atom

$$n_1 \to n_2 = \frac{E_{n2} - E_{n1}}{\text{electron charge}}$$

Ionization energy of hydrogen atom

It is the energy required to remove an electron from an atom

ex I.E.of Hydrogen = 0 – (– 13.6) = 13.6 eV.

Ionization Potential

It is the potential required correspongin to ionization energy in order to remove the electron fro the atom

$$= \frac{-E_n}{\text{electronic charge}}$$

X - RAYS

Produced by bombording high speed electrons on a target of high atomic weight and high melting point. The we basically highly magnetic photons.

	Soft X–ray	Hard X–ray
Wavelength	10 Å to 100 Å	0.1 Å – 10 Å
Energy	$\dfrac{12400}{\lambda}$ eV–Å	$\dfrac{12400}{\lambda}$ eV–Å
Penetrating power	Less	More
UseRadio photography	Radio therapy	

- Intensity of X-ray × current flowing through filament
- Rentetrating power × Applied Potential difference.

- Continous X-ray – Produce when electron while they hit the target
- Cutt-off wavelength – Mininum wavelength of continuous X-rays which appears when as electron loosses all its KE. in its first collision only. Hence producing photon of maximum energy and of minimum wavelength.

$\lambda_{min} = \frac{12400}{V} \text{Å}$, where V is applied potential difference

- Characteristic X-ray – Produce when electron hitting the metal target ejects on electron from shell and that vacant space when occupied by an electron from upper shell, produces a photon.

From Bohr Model

$n_1 = 1$, $n_2 = 2, 3, 4$.......K series

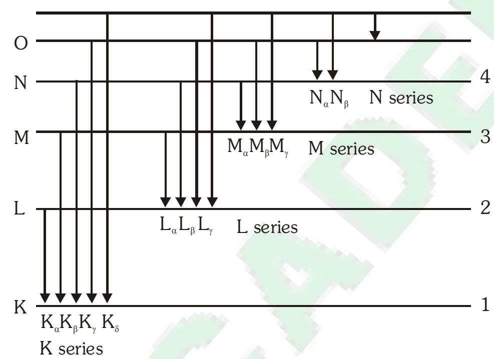
$n_1 = 2$, $n_2 = 3, 4, 5$.......L series

$n_1 = 3$, $n_2 = 4, 5, 6$.......M series

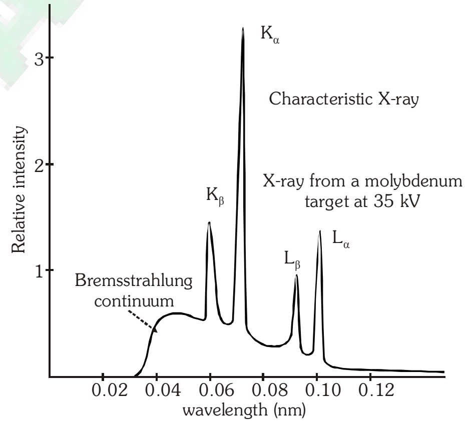
First line of series = α

Second line of series = β

Third line of series = γ



Transition	Wave– length	Energy	Energy difference	Wavelength
$L \to K$	$\lambda_{K\alpha}$	$h\nu_{K\alpha}$	$-(E_K - E_L)$	$\lambda_{K\alpha} = \frac{hc}{(E_K - E_L)}$
$(2 \to 1)$			$= h\nu_{K\alpha}$	$= \frac{12400}{(E_K - E_L)}$ eVÅ
$M \to K$	$\lambda_{K\beta}$	$h\nu_{K\beta}$	$-(E_K - E_M)$	$\lambda_{K\beta} = \frac{hc}{(E_K - E_M)}$
$(3 \to 1)$			$= h\nu_{K\beta}$	$= \frac{12400}{(E_K - E_M)}$ eVÅ
$M \to L$	$\lambda_{L\alpha}$	$h\nu_{L\alpha}$	$-(E_L - E_M)$	$\lambda_{L\alpha} = \frac{hc}{(E_L - E_M)}$
$(3 \to 2)$			$= h\nu_{L\alpha}$	$= \frac{12400}{(E_L - E_M)}$ eVÅ



MOSELEY'S LAW

$\sqrt{\nu} \propto (Z - b)$ where ν = frequancy of characteristic x-ray

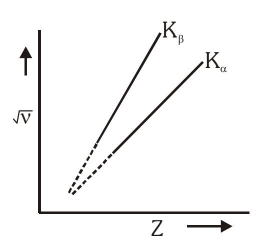
Z = atomic number of target

ν = frequency of characteristic spectrum

b = screening constant (for K– series b=1, L series b=7.4)

a = proportionality constant

$$\nu = RcZ^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$



Bohr model		Moseley's correction	
1.	For single electron species	1.	For many electron species
2.	$\Delta E = 13.6Z^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]eV$	2.	$\Delta E = 13.6\,(Z-1)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]eV$
3.	$\nu = RcZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	3.	$\nu = Rc(Z-1)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$
4.	$\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$	4.	$\frac{1}{\lambda} = R\,(Z-1)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

- For X–ray production, Moseley formulae are used because heavy metal are used.

When target is same $\lambda \propto \dfrac{1}{\frac{1}{n_1^2} - \frac{1}{n_2^2}}$ **When transition is same** $\lambda \propto \dfrac{1}{(Z-b)^2}$

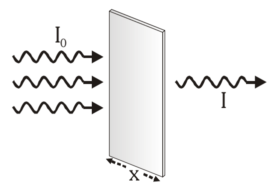
ABSORPTION OF X–RAY

$I = I_0 e^{-\mu x}$

where I_0 = Intensity of incident X–ray

I = Intensity of X–ray after passing through x distance

μ = absorption coefficient of material



- Intensity of X–ray decrease exponentially.
- Maximum absorption of X–ray $\rightarrow$ Lead
- Minimum absorption of X–ray $\rightarrow$ Air

Half thickness ($x_{1/2}$)

It is the distance travelled by X–ray when intensity become half the original value $x_{1/2} = \frac{\ell n_2}{\mu}$

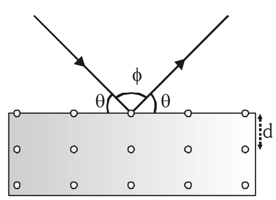
DIFFRACTION OF X–RAY

$2d \sin\theta = n\lambda$

where, d = spacing of crystal plane or lattice constant or distance between adjacent atomic plane

θ = Bragg's angle or glancing angle

ϕ = Diffracting angle n = 1, 2, 3 ....



For Maximum Wavelength

$\sin\theta = 1, n = 1 \Rightarrow \lambda_{max} = 2d$

so if $\lambda > 2d$ diffraction is not possible i.e. solution of Bragg's equation is not possible.

NUCLEAR PHYSICS

BINDING ENERGY

- Binding energy of a nucleus = Δmc^2

  where Δm = mass defect = $[Zm_p + (A-Z)m_n] - m_{nuc}$

  = Totall mass of nucleus mass of nucleus.

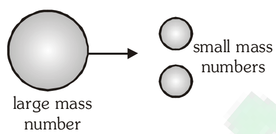
- Binding energy per nucleus = $\dfrac{\text{B.E.}}{\text{mass number}} = \dfrac{\text{B.E.}}{A}$

  Stability $\propto \dfrac{\text{B.E.}}{A}$

- $\dfrac{\text{B.E.}}{A}$ is maximum for A =62 (Ni), It is 8.79460 ± 0.00003 MeV/nucleon

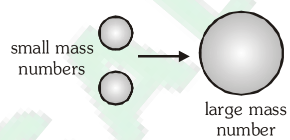
NUCLEAR FISSION

When heavy nuclei achieve stability by braking into two smaller nuclei, then it is called as nuclear fission reaction.



NUCLEAR FUSSION

When lighter nuclei achieve stability by combining and resulting into heavy nucleus and this reaction is called fusion reaction.



Q VALUE

It is teh theory released after trhe nuclei avhieve stability through nuclear fissiion or fussion reactions

It is always positive when the reaction occurs towards achieving more stability.

It Q value of a reaction is negative, it means taht reaction cannot occur as the products in that case will be more constable than the reaction.

NUCLEAR FISSION OF U^{235}

$U^{235} + {}_0n^1 \rightarrow Ba + Kr + 3\,{}_0n^1 + 200$ MeV or $U^{235} + {}_0n^1 \rightarrow Xe + Sr + 2\,{}_0n^1 + 200$ MeV

and many other reactions are possible.

- The average number of secondary neutrons is 2.5.
- Nuclear fission can be explained by using "liquid drop model" also.
- Δm is about 0.1% of mass of fissioned nucleus
- About 93% of released energy (Q) is appear in the form of kinetic energies of products and about 7% part in the form of γ – rays.

NATURAL URANIUM :

It is mixture of U^{235} (0.7%) and U^{238} (99.3%).

U^{235} is easily fissionable, by slow neutron (or thermal neutrons) having K.E. of the order of 0.03 eV. But U^{238} is fissionable with fast neutrons.

ENRICHED URANIUM

It contains 97% U^{238} and 3% U^{235}.

CRITICAL SIZE (OR MASS) :

It is minimum mass of uranium required to sustain a chain reacter.

REPRODUCTION FACTOR :

$$(K) = \frac{\text{rate of production of neutrons}}{\text{rate of loss of neutrons}}$$

(i) If K = 1; chain reaction is steady or sustained (As in nuclear reaction)

(ii) If K > 1; chain reaction will accelerate resulting in a explosion (As in atom bomb)

(iii) If K < 1; chain reaction will retard and will stop.

NUCLEAR REACTOR (K = 1) :

- **Nuclear Fuel :** U^{235}, Pu^{239} .Pu^{239} is the **best**. Its critical size is less than that of U^{235}. But Pu^{239} is not naturally available. So U^{235} is used in most of the reactors.
- **Moderator :** They are used to slow down the fast secondary neutrons D_2O, Graphite etc.
- **Control rods :** They are used absorbs slow neutrons e.g. Boron and Cadmium.
- **Coolant :** It is used to absorb heat and transfers it to water for further use.

FAST BREADER REACTORS

It is the atomic reactor in which fresh fissionable fuel (Pu^{239}) is produced along with energy. The amount of produced fuel (Pu^{239}) is more than consumed fuel (U^{235})

- **Fuel :** Used in this reactor Natural uranium.
- **Process :**

$${}_{92}U^{238} + {}_{0}n^{1} \longrightarrow {}_{92}U^{239} \xrightarrow{2\beta^{-}} {}_{94}Pu^{239} \text{ (best fuel of fission)}$$

- **Moderator :** Are not used in these reactors.
- **Coolant :** Liquid sodium

REQUIRED CONDITION FOR NUCLEAR FUSION

- **High temperature**
- **High Pressure (or density)**

HYDROGEN BOMB

Based on nuclear fusion and produces more energy than an atom bomb (based on nuclear fission).

PAIR PRODUCTION

e^- and e^+ pair is produced when in γ-photon having energy >, 1.02 MeV strikes a nucleus.

PAIR ANMIHILATION

When electron and positron combines, 2 γ-photon are formed, reach photon having energy >, 0.5 MeV.

RADIOACTIVITY

Radioactive Decays

- **α decay :** Occurs in nucleus having A>210
- **β decay :**
  - **A type**

    $(N/Z)_A > (N/Z)$ stable

    To achieve stability, it increases Z by conversion of neutron into proton

    $${}_{0}n^{1} \rightarrow {}_{1}p^{1} + e^{-1} + \bar{\nu},\ {}_{Z}X^{A} \rightarrow {}_{Z+1}Y^{A} + \underset{(\beta \text{ particle})}{e^{-1}} + \bar{\nu}$$

    This decay is called β^{-1} decay.

    Kinetic energy available for e^{-1} and $\bar{\nu}$ is, $Q = K_\beta + K_{\bar{\nu}}$

- **B type**
  $(N/Z)_B < (N/Z)$ stable
  To achieve stability it decreases Z by the conversion of a proton into neutron. That is,

  $$p \rightarrow n + \underset{(\text{positron})}{e^+} + \underset{(\text{neutrino})}{\nu}\ ,\ {}_{Z}X^{A} \rightarrow {}_{Z-1}Y^{A} + \underset{(\beta^+\text{particle})}{e^+} + \nu$$

- **γ decay :** When daughter nucleus in higher energy state comes to ground state. by emitting a photon or photons. a r photon is released.

  e.g. $${}^{67}_{27}Co \rightarrow \underset{(\text{higher energy state})}{{}^{67}_{28}Ni^*} + \beta^- + \bar{\nu}\ ,\ {}^{67}_{28}Ni^* \rightarrow {}^{67}_{28}Ni + \gamma \text{ photon}$$

Properties of α, β and γ rays

Features	**α–particles**	**β–particles**	**γ–rays**
Identity	Helium nucleus or doubly ionised helium atom ($_2He^4$)	Fast moving electrons ($_{-}\beta^0$ or β^-)	Electromagnetic wave (photons)
Charge	Twice of proton (+2e) $\approx 4m_p$	Electronic (– e)	Neutral
Mass	(rest mass of β) m_p–mass of proton	rest mass = 0 = (rest mass of electron)	
Speed	1.4×10^7 m/s. to 2.2×10^7 m/s. (Only certain value between this range). Their speed depends on nature of the nucleus. So that it is a characteristic speed.	1% of c to 99% of c (All possible values between this range) β–particles come out with different speeds from the same type of nucleus. So that it can not be a characteristic speed.	Only $c = 3 \times 10^8$ m/s γ–photons come out with same speed from all types of nucleus. So, can not be a characteristic speed.
K.E.	≈ MeV	≈ MeV	≈ MeV
Energy spectrum	Line and discrete (or linear)	Continuous (or linear)	Line and discrete
Ionization power (α>β>γ)	10,000 times of γ–rays	100 times of γ–rays (or $\frac{1}{100}$ times of α)	1 (or $\frac{1}{100}$ times of β)
Penetration power (γ>β>α)	$\frac{1}{10000}$ times of γ–rays	$\frac{1}{100}$ times of γ–rays (100 times of α)	1(100 times of β)
Effect of electric or magnetic field	Deflection	Deflection (More than α)	No deflection
Explanation of emission	By Tunnel effect (or quantum mechanics)	By weak nuclear interactions	With the help of energy levels in nucleus

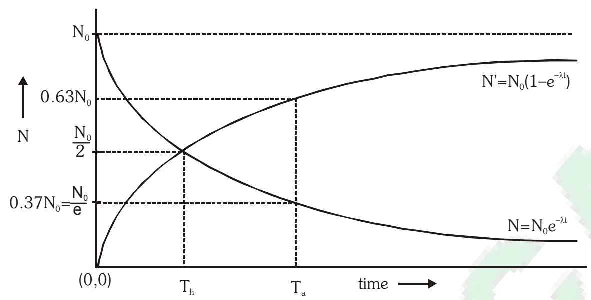
Laws of Radioactive Decay

Rate of decay $\propto$ number of nuclei.

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

where λ is called the decay constant. This equation may be expressed in the form $\frac{dN}{N} = -\lambda dt$.

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



- **Half life (T_h)** : Time during which number of active nuclei reduce to half of initial value.

$$T_h = \frac{\ell n(2)}{\lambda}$$

- **Mean or Average Life (T_a)** : It is the average of age of all active nuclei i.e.

$$T_a = \frac{\text{sum of times of existance of all nuclei in a sample}}{\text{initial number of active nuclei in that sample}} = \frac{1}{\lambda}$$

ACTIVITY OF A SAMPLE (A OR R) (OR DECAY RATE)

$$R = -\frac{dN}{dt} = N\lambda \text{ or } R = R_0 e^{-\lambda t}$$

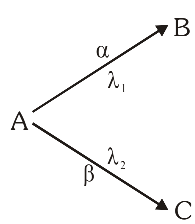
SI UNIT of R : 1 becquerel (1 Bq)= 1 decay/sec
Other Unit is curie : 1 Ci = 3.70×10^{10} decays/sec
1 Rutherford : (1 Rd) = 10^6 decays/s
Specific activity : Activity of 1 gm sample of radioactive substance. Its unit is Ci/gm
e.g. specific activity of radium (226) is 1 Ci/gm.

- **Parallel radioactive disintegration**

$$\Rightarrow \frac{dN_A}{dt} = -(\lambda_1 + \lambda_2) N_A$$

$$\Rightarrow \lambda_{eff} = \lambda_1 + \lambda_2$$

$$\Rightarrow t_{eff} = \frac{t_1 t_2}{t_1 + t_2}$$



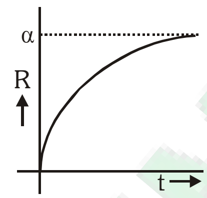
Radioactive Disintegration with Successive Production

$$\xrightarrow[(\alpha = \text{rate of production})]{\alpha} A \xrightarrow{\lambda} B$$

$$\frac{dN_A}{dt} = \alpha = \lambda N_A \text{ ....(i)}$$

when N_A in maximum $\frac{dN_A}{dt} = 0 = \alpha - \lambda N_A = 0$, N_A or max $= \frac{\alpha}{\lambda}$

$$\int_0^t \frac{dN_A}{\alpha - \lambda N_A} = \int_0^t dt,$$ Number of nuclei is $N_A = \frac{\alpha}{\lambda}\left(1 - e^{-\lambda t}\right)$



Soddy and Fajan's Group Displacement Laws :

(i) **α–decay :** After emission of one α–particle reduces the mass number by 4 units and atomic number by 2 units. ${}_{Z}X^{A} \rightarrow {}_{Z-2}Y^{A-4} + {}_{2}He^{4}(\alpha)$

(ii) **β–decay :** Mass number remains same and atomic bumber increases by 1. ${}_{Z}X^{A} \rightarrow {}_{Z+1}Y^{A} + \beta + \bar{\nu}$

(iii) **γ–decay :** Both mass number and atomic number remains same, only energy is released in the form of γ–photons.