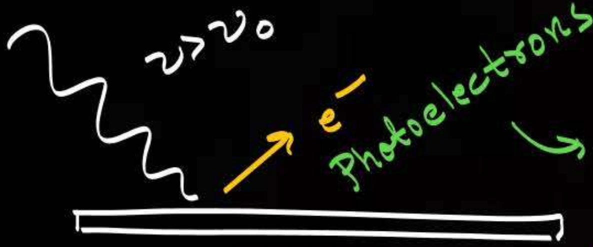
TOPICS TO BE COVERED

1. Dual Nature Of Matter and radiation
2. Atoms
3. Nuclie
4. Questions

Photo Electric Effect:



$\rightarrow$ Rate of flow $\rightarrow$ Photo Current

$$\boxed{\phi = h\nu_0 = \frac{hc}{\lambda_0}}$$

Metal

Photo electric Effect

(Metal dependent)

- **Threshold Frequency:** Min freq from which PEE Can be started.
  (ν_0)

- **Work Function:** ϕ = Min Energy Required to Remove e^- from Metal.
  $\phi = h\nu_0$.

- **Cut off wavelength:** Max wavelength upto which PEE will Occur.
  λ_0

Imp point Intensity $\propto$ no of e^- emit $\propto$ Photo Current

I↑ Photo Current ↑

I↓ " ↓

* freq of Light $\Rightarrow$ KE of e^-

$\boxed{\nu\uparrow \quad KE\uparrow}$

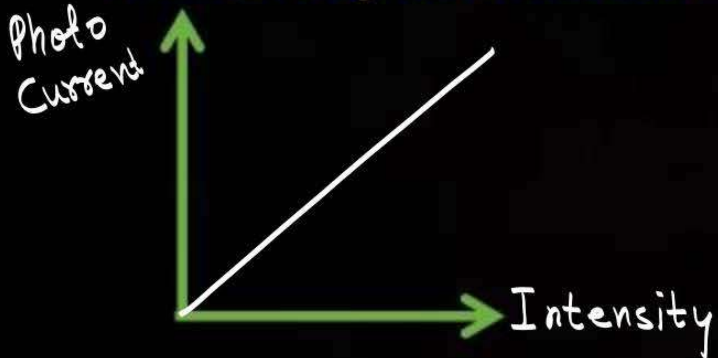
$\nu\uparrow$ KE↑ More Stopping Pot is Req.

ν never decide Current

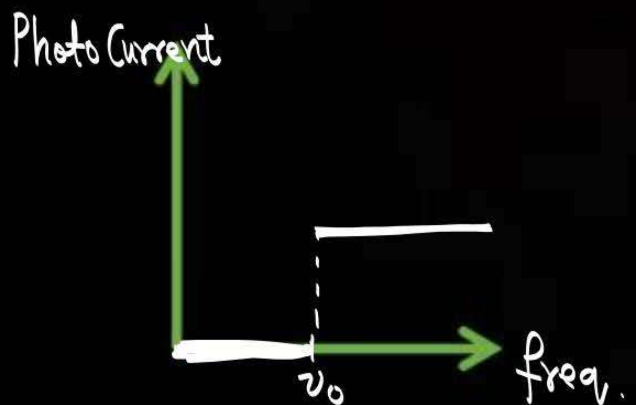
Intensity never decide V_{STOP}

Observations Made in Experiment:

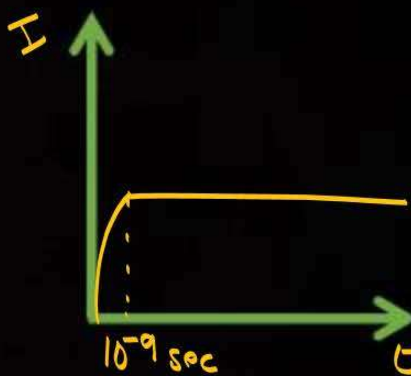
1. Intensity Vs Photocurrent:



2. Photocurrent Vs Frequency:



3. Photocurrent Vs time:

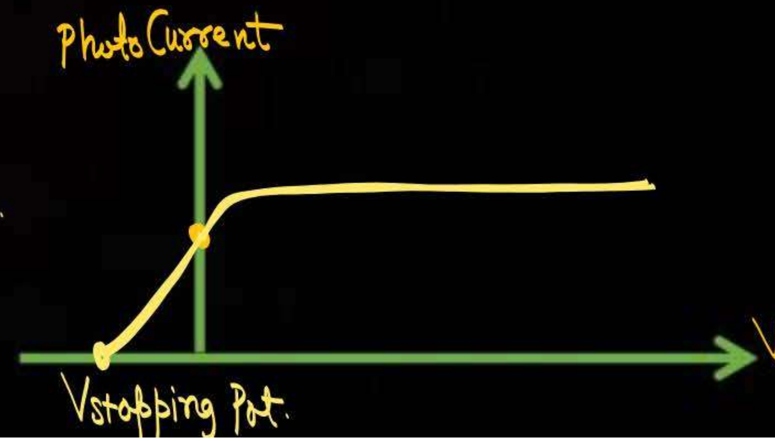


$\nu > \nu_0$

Instantaneous Process.

4. Photocurrent Vs Voltage:

Imp.



4. Photocurrent Vs Voltage (a) Different Intensity (b) Different Frequency:

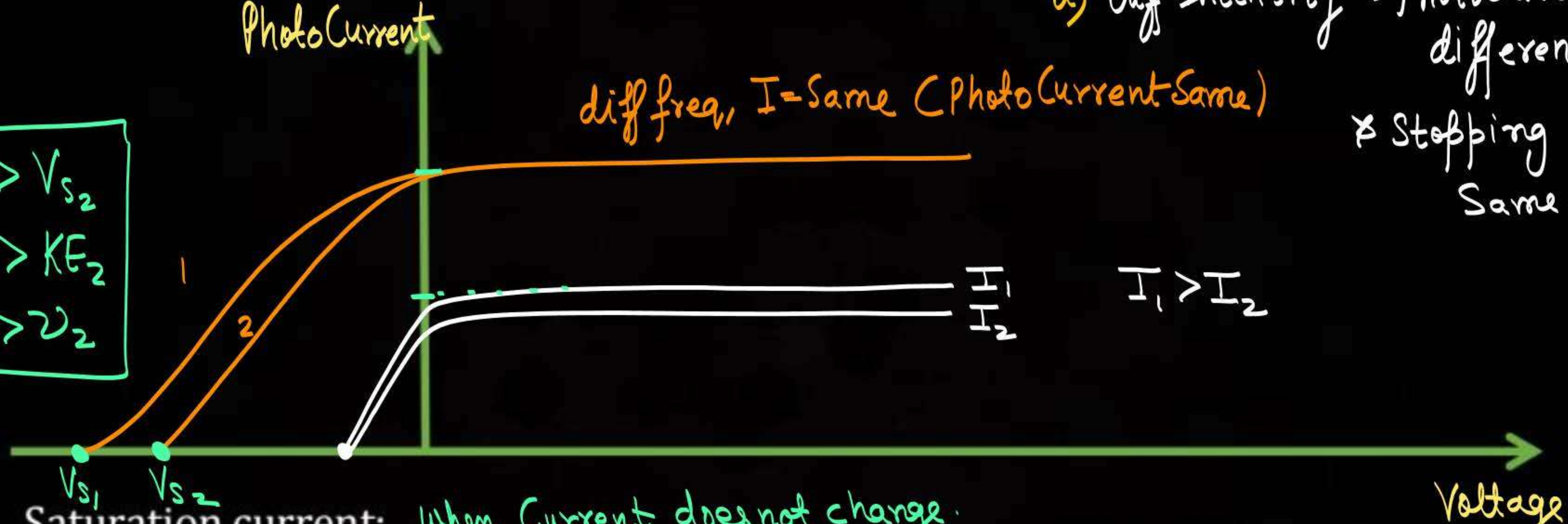
a) diff Intensity → PhotoCurrent different

∗ Stopping Pot Same.

$V_{s_1} > V_{s_2}$

$KE_1 > KE_2$

$\nu_1 > \nu_2$



Saturation current: When Current does not change.

b) diff freq,

Stopping potential "–ve voltage of Collector at which Photo Current = 0".

Why wave theory failed?

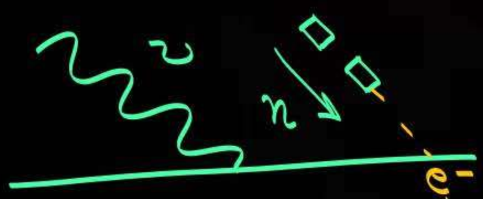
- According to wave theory when light incident on surface, energy is distributed continuously over the surface. So that electron must take a time travel to accumulate sufficient energy to come out. But in experiment there is no time lag.

- When intensity is increased, more energetic electrons should be emitted. So that stopping potential should be intensity dependent. But it is not observed.

- According to wave theory, if intensity is sufficient then, at each frequency, electron emission is possible. It means there should not be existence of threshold frequency

Einstein Explanation of Photoelectric effect

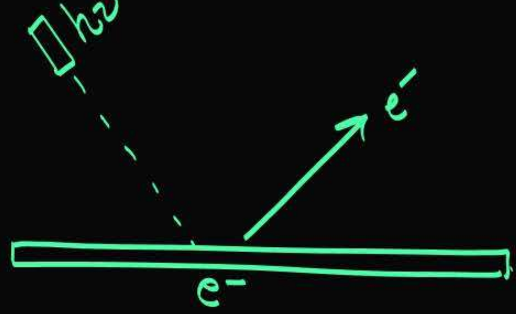
- Radiation observed by metal are in form of quanta (photon). Energy of each photon depends on frequency.
- One photon interact with one electron only and interaction is instantaneous process in which the photon transfer complete energy to the electron
- The intensity of light is directly proportional to no of photons, hence if intensity increases the no of photon incident increases which leads to more emission of electrons (rise of photocurrent)
- During the interaction the energy and momentum is conserved.
- Einstein's equation of P.E.E

1. 

Energy of Each photon = $h\nu$

Energy of n photons = $nh\nu$.

$\boxed{\text{Intensity} \propto \text{no of Photons}}$



Max KE of e^-

$$E_i = \phi + KE_{e^-}$$

$$\boxed{h\nu = h\nu_0 + \frac{1}{2}mv^2}$$

(*)

$$\boxed{h\nu = h\nu_0 + \frac{1}{2}mv^2}$$

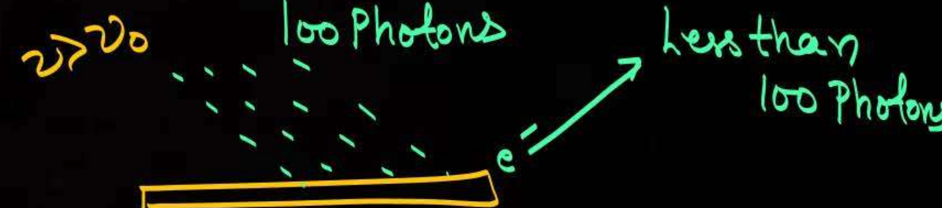
$$\boxed{\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + \frac{1}{2}mv^2}$$

$$\boxed{h\nu = h\nu_0 + eV_s}$$

$$\boxed{KE = eV_s}$$

Einstein Explanation of Photoelectric effect

- If the frequency of light increases the kinetic energy of photo electron increases. hence the stopping potential.
- No of photons incident is not equal to no of electron emitted.
- For a given incident frequency, the kinetic energy of emitted electron is not same only few electrons have maximum Kinetic energy



AT Relation

$$h\nu = \phi_0 + KE$$

Metal dependent

More V_s is Req.

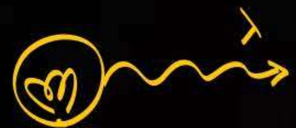
$$\text{Photo Electric Efficiency} = \frac{\text{no of } e^- \text{ emitted}}{\text{no of Photons abs.}}$$

Important Points:

$$\eta_p = \frac{P_{bulb}}{E_{photon}}$$

- Photons emitted per second from a source

Energy of Each Photon $= \frac{hc}{\lambda}$



Power $= P_0$

N photons $E = \frac{Nhc}{\lambda}$

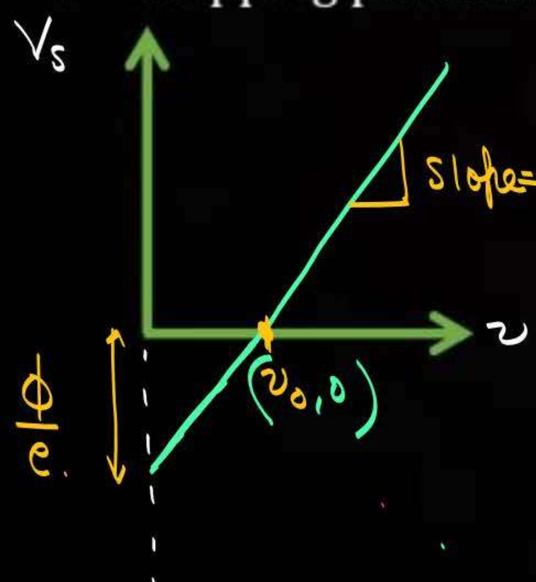
E_p

$\text{Power} = \frac{\text{Energy}}{\text{time}} = \left(\frac{N}{t}\right)\left(\frac{hc}{\lambda}\right)$

$P = \eta_p E_p$

$\hookrightarrow$ no of Photons/sec

- Stopping potential and frequency:



$h\nu = \phi + eV_s$

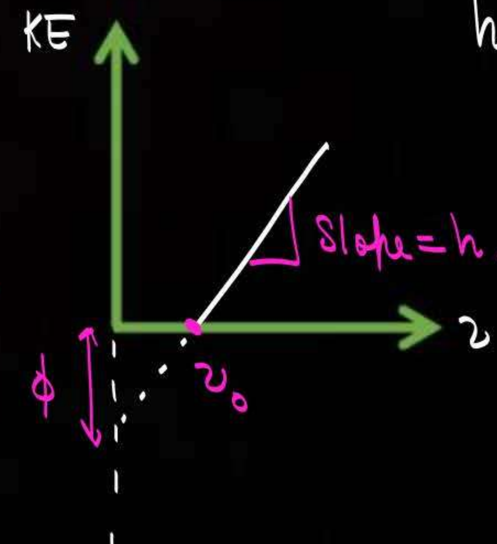
$eV_s = h\nu - \phi$

$V_s = \frac{h}{e}\nu - \frac{\phi}{e}$

Slope Intercept

- Planck's Constant
- Work Function
- Threshold Frequency

- Kinetic Energy and frequency:



$h\nu = \phi + KE$

$KE = h\nu - \phi$

$y = mx - c$

Q. The figure shows the variation of photocurrent with anode potential for a photosensitive surface for three different radiations. Let I_a, I_b and I_c be the intensities and f_a, f_b and f_c be the frequencies for the curves a, b and c respectively. **[2004]**

Ans : A

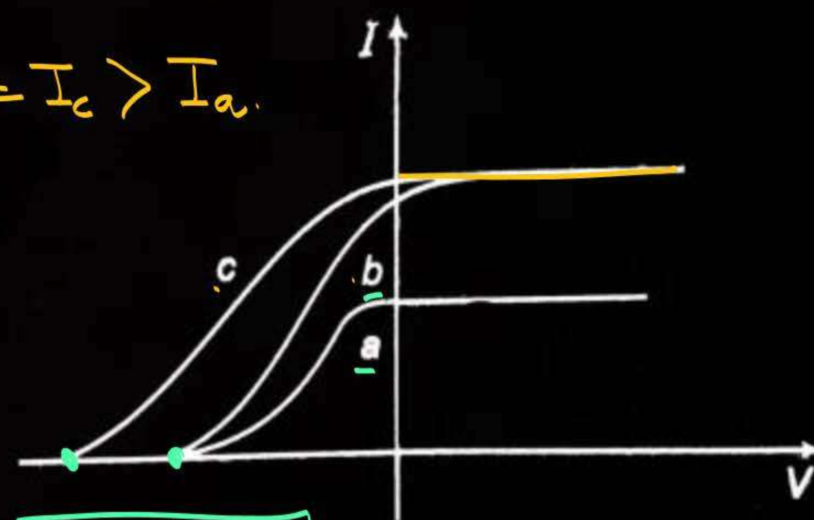
(A) $f_a = f_b$ and $I_a \neq I_b$ ✓

(B) $f_a = f_c$ and $I_a = I_b$

(C) $f_a = f_b$ and $I_a = I_b$

(D) $f_b = f_c$ and $I_b = I_c$

$I_b = I_c > I_a$



$\boxed{f_c > f_a = f_b}$

Q. Given figure shows few data points in a photo electric effect experiment for a certain metal. The minimum energy for ejection of electron from its surface is (Plancks constant $h = 6.62 \times 10^{-34}$ J. S)

[JEE Mains 2020 7 September (Morning)]

Ans : B

(A) 2.59eV

(B) 2.27eV

(C) 1.93eV

(D) 2.10eV

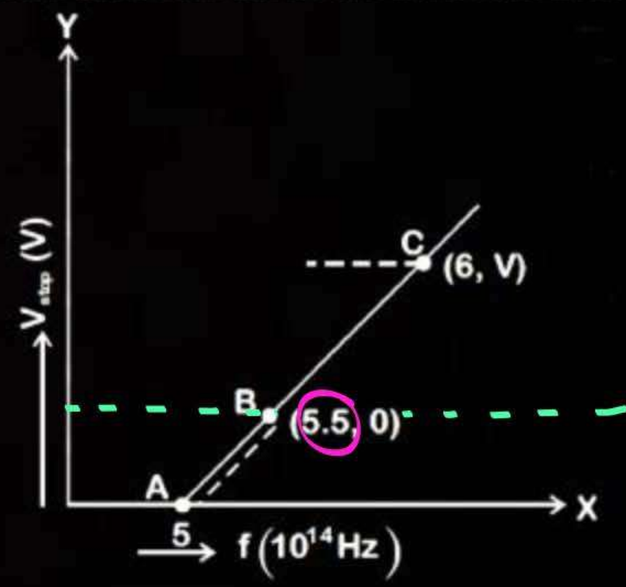
ϕ = work function

$\phi = h\nu_0$

$\phi = 6.62 \times 10^{-34} \times 5.5 \times 10^{14}$

In eV.

$\phi = \frac{6.62 \times 10^{-34} \times 5.5 \times 10^{14}}{1.6 \times 10^{-19}}$



Q. The electric field of light wave is given as $E = 10^{-3}\cos\left(\frac{2\pi x}{5\times10^{-7}} - 2\pi \times 6 \times 10^{14} t\right)\hat{x}\ NC^{-1}$. This light falls on a metal plate to work function 2eV. The stopping potential of the photoelectrons is **[Main 2019]**

(Given, E (in eV) $= \frac{12375}{\lambda \text{ (in Å)}}$)

Ans : A

(A) 0.48 eV

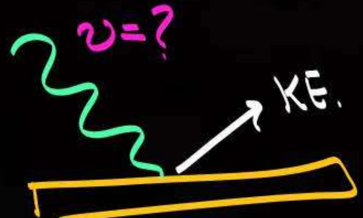
(B) 0.72 eV

(C) 2.0 eV

(D) 2.48 eV

$E = E_0 \cos(\underset{\frac{2\pi}{\lambda}}{Kx} - \underset{2\pi\nu}{\omega t})$

$E = 10^{-3}\cos\left(\frac{2\pi x}{5\times10^{-7}} - 2\pi 6\times10^{14} t\right)$



$\phi = 2eV.$

λ

$\cancel{2\pi} 6\times10^{14} = \cancel{2\pi}\nu$

$\nu = 6\times10^{14}$ Hz

Incident freq.

$E_i = \phi + eV_s$

$= 2eV + eV_s$

$\lambda_i = 5\times10^{-7} = 5000$ Å

$E_i = \frac{12375}{5000}$ eV

Q. The magnetic field associated with a light wave is given at the origin, by $B = B_0[\sin(3.14 \times 10^7)ct + \sin(6.28 \times 10^7)ct]$. If this light falls on a silver plate having a work function of 4.7 eV, what will be the maximum kinetic energy of the photoelectrons? **[Main 2019]**

(Take, $c = 3 \times 10^8\ ms^{-1}$ and $h = 6.6 \times 10^{-34}$ J-s)

ϕ

Ans : A

(A) 7.72 eV ϕ

(B) 6.82 eV

(C) 8.52 eV

(D) 12.5 eV

ω_2

$(2\pi \times 10^7 c)$

$$B = B_0\left[\sin(\underbrace{3.14\times10^7}_{\substack{\omega_1 \\ \nu_1}})ct + \sin(\underbrace{6.28\times10^7}_{\substack{\omega_2 \\ \nu_2 \text{ (more)}}})ct\right]$$

$\boxed{\omega = 2\pi\nu}$

$\hookrightarrow KE_{e^-} \rightarrow$ more.

$E_i = \phi + KE$

$\boxed{E_i = 4.7\text{eV} + KE}$

$\phi = 4.7$ eV.

$\nu \rightarrow KE.$

$\omega_2 = (\cancel{2\pi} c \times 10^7) = \cancel{2\pi} \upsilon_2$

Since it is more than ω_1

its KE_e will be More.

$\upsilon_2 = c \times 10^7$

$\boxed{\upsilon_2 = 3 \times 10^8 \times 10^7}$

$E_1 = h\upsilon = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^{15}}{1.6 \times 10^{-19}}$

$E_1 = \quad (eV)$

$\boxed{E_1 = \phi + KE}$

Q. In a photoelectric experiment, the wavelength of the light incident on a metal is changed from 300 nm to 400 nm. The decrease in the stopping potential is close to $\left(\frac{hc}{e} = 1240\, nmV\right)$ **[Main 2019]**

Ans : D

A 0.5 V

B 2.0 V

C 1.5 V

D 1.0 V

Q. A metal surface is illuminated by light of two different wavelength 248 nm and 310 nm. The maximum speeds of the photoelectrons corresponding to these wavelengths are μ_1 and μ_2, respectively. If the ratio $\mu_1 : \mu_2 = 2 : 1$ and hc = 1240 eV nm, the work function of the metal is nearly

[2014 Adv.]

Ans : A

A 3.7 eV

B 3.2 eV

C 2.8 eV

D 2.5 eV

De-Broglie Hypothesis

De-broglie assumed that as an EM wave can posses momentum and behave like particle, a moving particle must also behave like and EM wave of which wavelength can be given as

m $\longrightarrow v$

Matter wave

$$\boxed{\lambda = \frac{h}{mv} = \frac{h}{p}}$$

EM wave λ $\Rightarrow$ Photon $\longrightarrow$ momentum

$$\boxed{p = \frac{h}{\lambda}}$$

for a Photon

$$E = \frac{hc}{\lambda}$$

p

$$\boxed{E = pc}$$

Momentum

Method of calculation of de Broglie wavelength

De-broglie wavelength

Frame of Ref

m, v: $\lambda = \dfrac{h}{mV}$

m, v_1

Rest

v_1

$$\boxed{\lambda' = \frac{h}{m v_{rel}}}$$

Collisions Problem Mechanics

λ_2, u_2, u_1, m_2, m_1, λ_1

v_2, v_1, m_2, m_1

e = Coefficient of Rest.

$$v_1 = \frac{(m_1 - e m_2)u_1 + (1+e) m_2 u_2}{m_1 + m_2}$$

$$v_2 = \frac{(m_2 - e m_1)u_2 + (1+e) m_1 u_1}{m_1 + m_2}$$

$$\lambda_{f_1} = \frac{h}{m v_{f_1}}$$

$$\lambda_{f_2} = \frac{h}{m v_{f_2}}.$$

m, v

$$\lambda = \frac{h}{mv} = \frac{h}{P}$$

m, KE

$$\lambda = \frac{h}{\sqrt{2mKE}}.$$

Pot diff

ΔV, KE

$KE = q\Delta V$

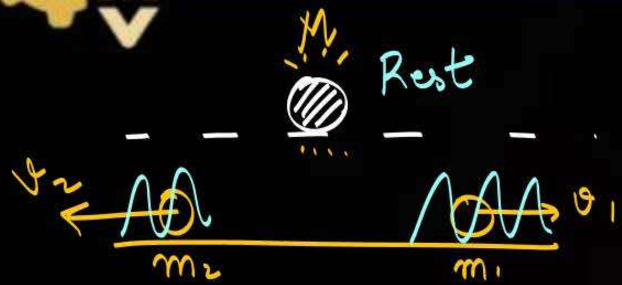
$$\lambda = \frac{h}{\sqrt{2mq\Delta V}}$$

- electron $= \dfrac{12.2}{\sqrt{V}}$ Å
- proton $= \dfrac{0.286}{\sqrt{V}}$ Å.
- deutron $= \dfrac{0.202}{\sqrt{V}}$ Å
- α particle $= \dfrac{0.101}{\sqrt{V}}$ Å.

Method of calculation of de Broglie wavelength

De-broglie wavelength

Explosion



$\lambda_2 = \frac{h}{m_2 v_2}$ $\qquad$ $\lambda_1 = \frac{h}{m_1 v_1}$

$f_{ext} = 0$

$\vec{P_i} = \vec{P_f}$

$\boxed{m_1 v_1 = m_2 v_2 = p}$

KTG

dof $= 3A - R$

- mono − 3
- diatomic − 5
- Triatomic = 7

Energy = law of Equipartition of Energy $\boxed{E_{dof} = \frac{1}{2}KT}$

$E = \frac{f}{2}K_B T$

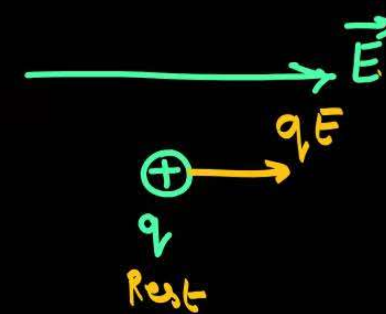
$\lambda = \frac{h}{\sqrt{2mKE}} = \frac{h}{\sqrt{fmKT}}$

Electric field

$a = \frac{qE}{m}$

$v = u + at$

$\lambda = \frac{h}{mv}$



Magnetic field.

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

$r = \frac{mv}{qB} = \frac{P}{qB}$

$\boxed{\lambda = \frac{h}{P}} = \frac{h}{qBr}$

Q. A particle P is formed due to a completely inelastic collision of particles x and y having de-Broglie wavelengths λ_x and λ_y, respectively. If x and y were moving in opposite directions, then the de-Broglie wavelength of P is

(Main 2019)

Ans : B

(A) $\lambda_x - \lambda_y$

(B) $\dfrac{\lambda_x \lambda_y}{\lambda_x - \lambda_y}$ Ans

(C) $\dfrac{\lambda_x \lambda_y}{\lambda_x + \lambda_y}$

(D) $\lambda_x + \lambda_y$

$$\vec{P_x} + \vec{P_y} = \vec{P_f}$$

$$\frac{\cancel{h}}{\lambda_x} - \frac{\cancel{h}}{\lambda_y} = \frac{\cancel{h}}{\lambda_p}$$

$$\lambda_p = \frac{\lambda_x \lambda_y}{\lambda_y - \lambda_x}$$

Collision

$F_{ext} = 0$

$\vec{P_i} = \vec{P_f}$

Q. A particle of mass M at rest decays into two particles of masses m_1 and m_2 having non-zero velocities. The ratio of the de-Broglie wavelengths of the particles λ_1/λ_2 is **(1999)**

Ans : C

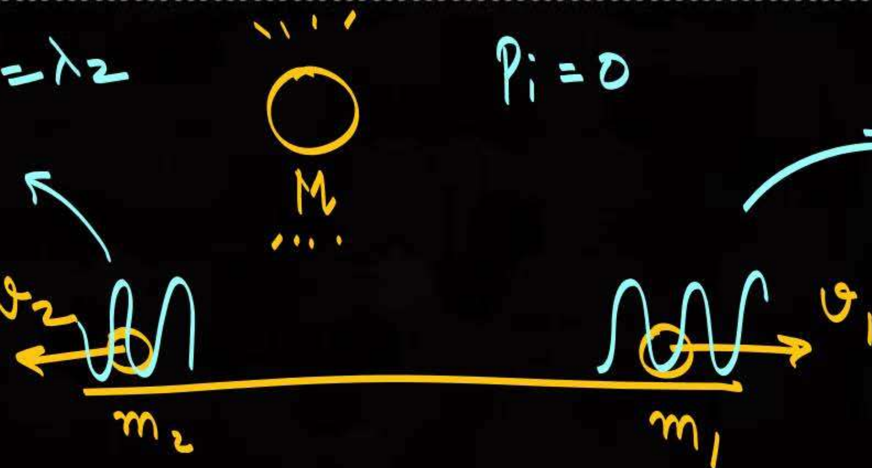
A m_1/m_2

B m_2/m_1

C 1 Ans

D $\sqrt{m_2}/\sqrt{m_1}$

$\frac{h}{p} = \lambda_2$ $p_i = 0$ $\lambda_1 = \frac{h}{p}$



$p_f = 0$ $\boxed{m_1 v_1 = m_2 v_2 = p}$

$\frac{\lambda_1}{\lambda_2} = 1$

Q. A particle A of mass 'm' and charge 'q' is accelerated by a potential difference of 50 V. Another particle B of mass '$4m$' and charge 'q' is accelerated by a potential difference of 2500 V. The ratio of de-Broglie wavelengths $\frac{\lambda_A}{\lambda_B}$ is close to

(Main 2019)

Ans : D

A) 4.47

B) 10.00

C) 0.07

D) 14.14

Q. Two particles move at right angle to each other. Their de-Broglie wavelengths are λ_1 and λ_2, respectively. the particles suffers perfectly inelastic collision. The de-Broglie wavelength λ of the final particle, is given by **(Main 2019)**

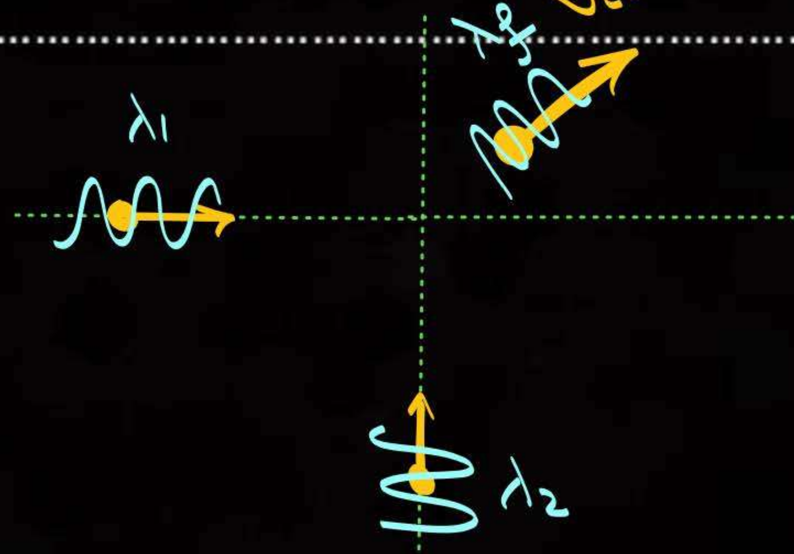
Ans : A

(A) $\dfrac{1}{\lambda^2} = \dfrac{1}{\lambda_1^2} + \dfrac{1}{\lambda_2^2}$ Ans

(B) $\lambda = \sqrt{\lambda_1 \lambda_2}$

(C) $\lambda = \dfrac{\lambda_1 + \lambda_2}{2}$

(D) $\dfrac{2}{\lambda} = \dfrac{1}{\lambda_1} + \dfrac{1}{\lambda_2}$



$F_{ext} = 0$

$\vec{P_i} = \vec{P_f}$

$|\vec{P_i}| = |P_f|$

$\sqrt{\dfrac{h^2}{\lambda_1^2} + \dfrac{h^2}{\lambda_2^2}} = \dfrac{h}{\lambda_f}$

$\boxed{\dfrac{1}{\lambda_1^2} + \dfrac{1}{\lambda_2^2} = \dfrac{1}{\lambda^2}}$

Q. An electron of mass m with an initial velocity $\vec{V} = V_0\hat{\imath}$ $(V_0 > 0)$ enters an electric field $\vec{E} = -E_0\hat{\imath}$ (E_0 = constant > 0) at $t = 0$. If λ_0 is its de-Broglie wavelength initially, then its de-Broglie wavelength at time t is –

Ans : A

(A) $\dfrac{\lambda_0}{\left(1 + \dfrac{eE_0}{mV_0}t\right)}$ Ans

(B) $\lambda_0\left(1 + \dfrac{eE_0}{mV_0}t\right)$

(C) $\lambda_0 t$

(D) λ_0

E_0

$qE \longrightarrow a = \dfrac{eE_0}{m}$

$-e$ m $v_0\hat{\imath}$ λ_f v

$t = 0$

$\lambda_0 = \dfrac{h}{mv_0}$

$v = u + at$

$v = v_0 + \dfrac{eE}{m}t$

$\lambda_f = \dfrac{h}{mv_0\left[1 + \dfrac{eE}{mv_0}t\right]} = \dfrac{\lambda_0}{\left[1 + \dfrac{eE}{mv_0}t\right]}$

$\lambda_f = \dfrac{h}{mv_f} = \dfrac{h}{m\left(v_0 + \dfrac{eE}{m}t\right)}$

Q. An electron (mass m) with an initial velocity $\vec{v} = v_0\hat{\imath}$ is in an electric field $\vec{E} = E_0\hat{\jmath}$. If $\lambda_0 = \dfrac{h}{mv_0}$, it's de Broglie wavelength at time t is given by

H.W

Ans : C

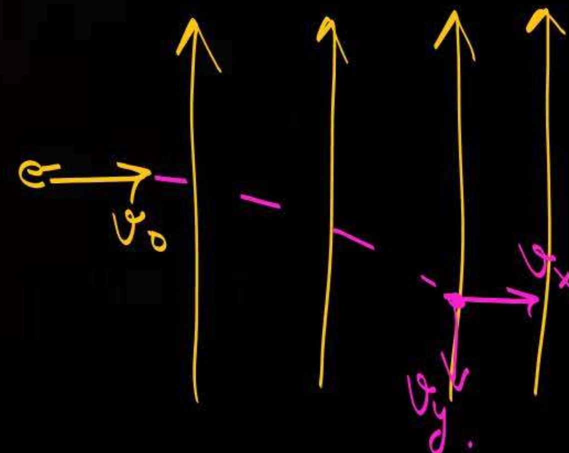
Parabola

(A) λ_0

(B) $\lambda_0\sqrt{1 + \dfrac{e^2E_0^2t^2}{m^2v_0^2}}$

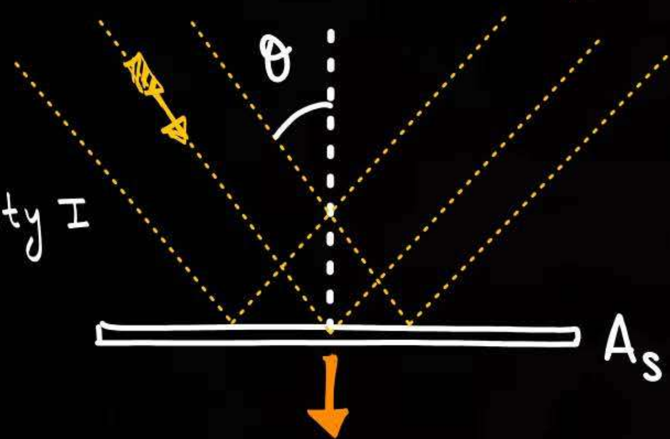
(C) $\dfrac{\lambda_0}{\sqrt{1 + \dfrac{e^2E_0^2t^2}{m^2v_0^2}}}$

(D) $\dfrac{\lambda_0}{\left(1 + \dfrac{e^2E_0^2t^2}{m^2v_0^2}\right)}$



Radiation Force and Pressure

light of Intensity I



$\theta = 0°$

$$\boxed{F_\perp = \frac{2IA}{c}}$$

$$\boxed{\text{Pressure} = \frac{F}{A} = \frac{2I}{c}}$$

I

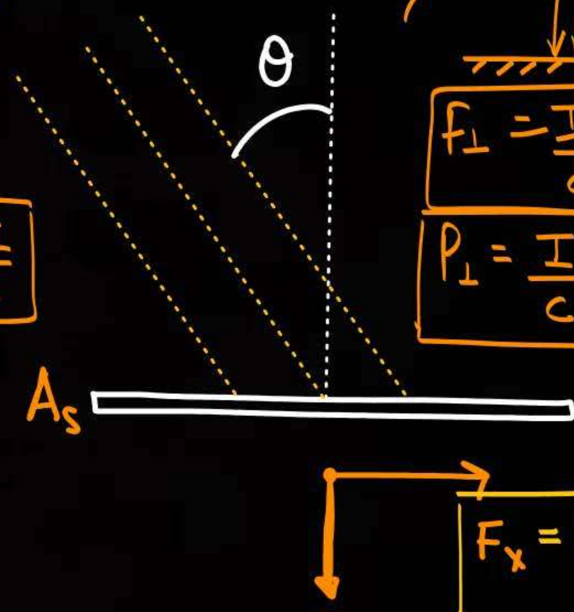
A_s (100% reflection)

$$\boxed{F_{Plate} = \frac{2 I A_s \cos^2\theta}{c}}$$

A_s = Area of Surface

$\theta = \angle$ of incidence

I = Intensity, c = speed of light.



$\theta = 0°$

$$\boxed{F_\perp = \frac{IA}{c}}$$

$$\boxed{P_\perp = \frac{I}{c}}$$

$f_x = 0$ along surface

A_s (100% absorb

$$\boxed{F_x = \frac{I A_s \sin\theta \cos\theta}{c}}$$

F_y

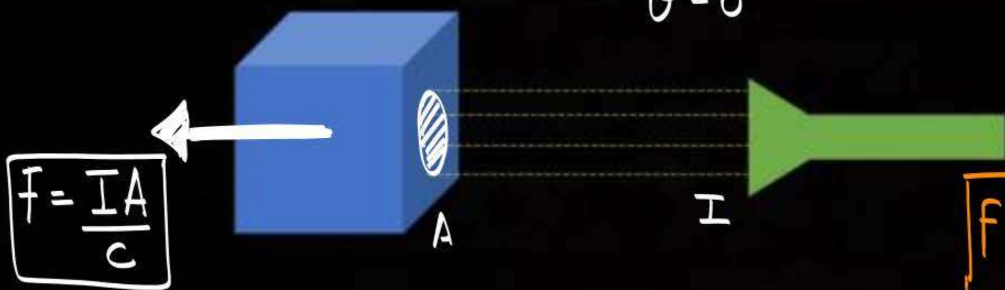
$$\boxed{F_y = \frac{I A_s \cos^2\theta}{c}}$$

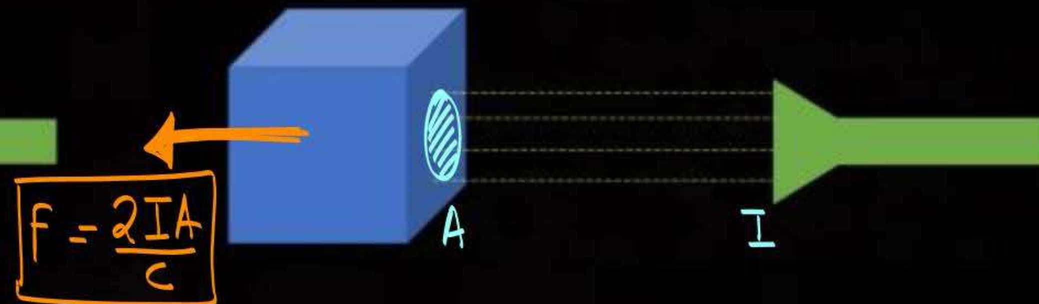
Normal incidence case

1. Perfectly black body $(a=1)$

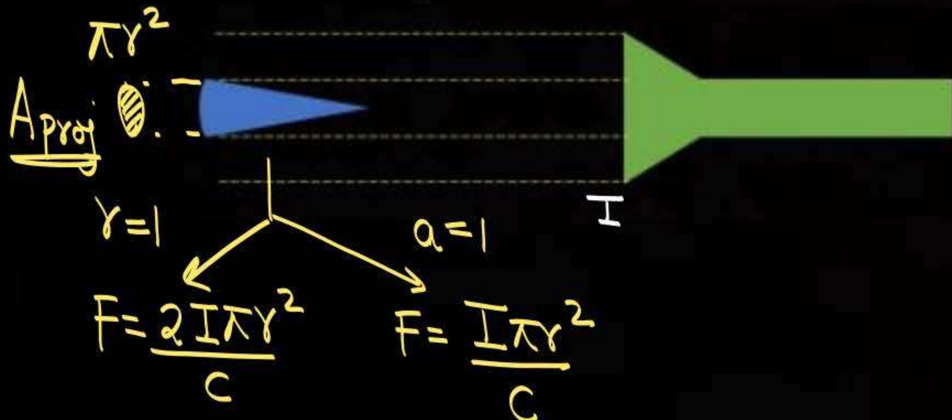
2. Perfectly reflecting body $(r=1)$

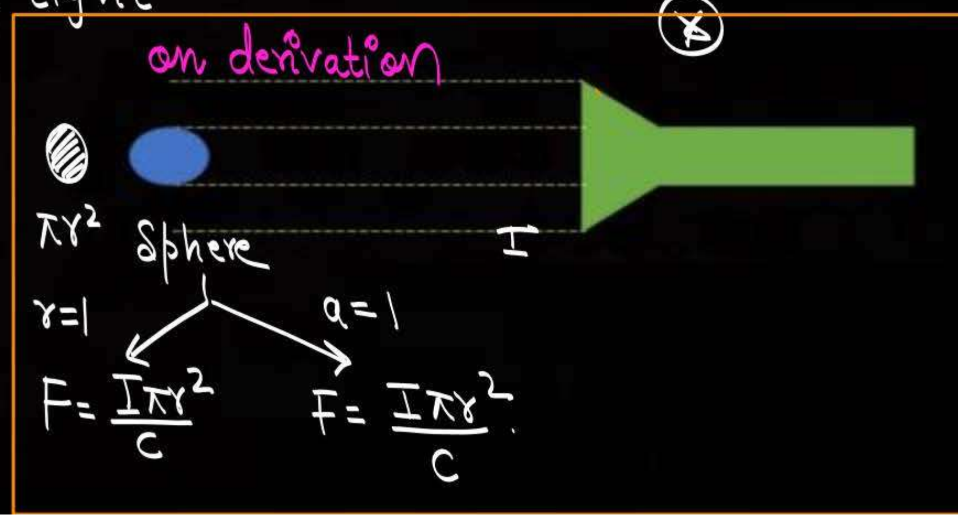
$\theta = 0°$





When an object is placed in path of light





$\gamma = 1$

Q. Light of intensity I is incident normally on a perfectly reflecting plate of area A kept in a gravity free space. If the photons strike the plate symmetrically and initially the spring was at its natural length, find the maximum compression in the springs

Ans : B

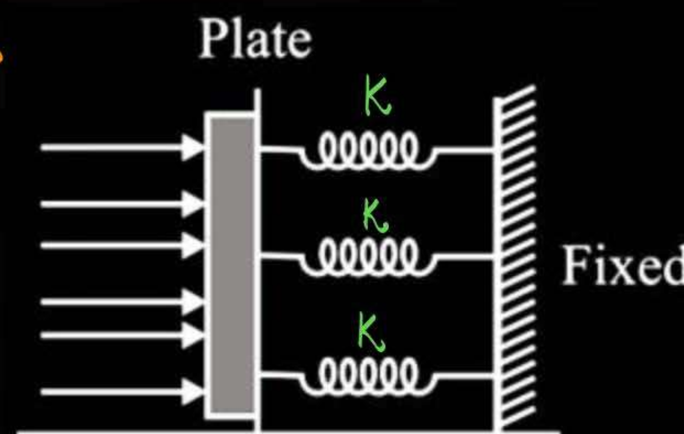
$K_{parallel} = K_1 + K_2 + K_3$

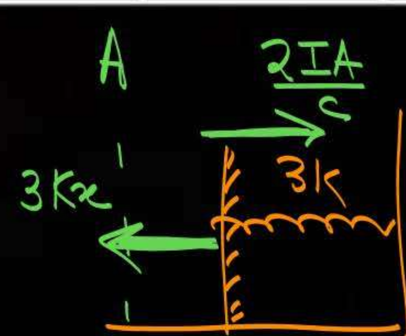
$= 3K$

at Equilibrium

$3Kx = \frac{2IA}{c}$

$$\boxed{x = \frac{2IA}{3Kc}}$$





(A) IA/KC

(B) $2IA/3KC$ Ans

(C) $3IA/KC$

(D) $4IA/3KC$

Q. A small plane mirror (perfectly reflecting) of area A and mass M is hanging vertically with the help of a mass less strong of length l. Light of intensity I is incident Perpendicular on it. Find angle made by the string with the vertical.

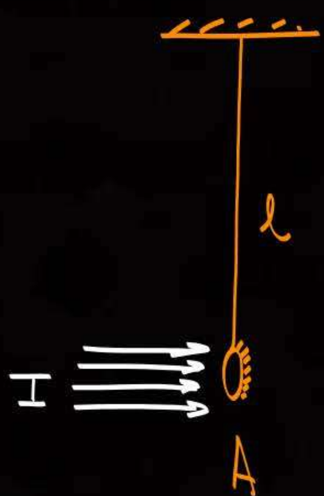
Ans :D

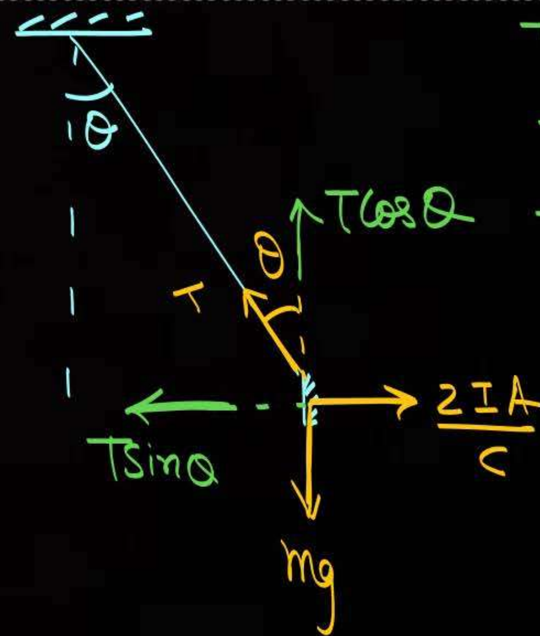
(A) $\theta = \tan^{-1}\frac{IA}{mgc}$

(B) $\theta = \sin^{-1}\frac{I2A}{mgc}$

(C) $\theta = \sin^{-1}\frac{IA}{mgc}$

(D) $\theta = \tan^{-1}\frac{2IA}{Mgc}$ Ans





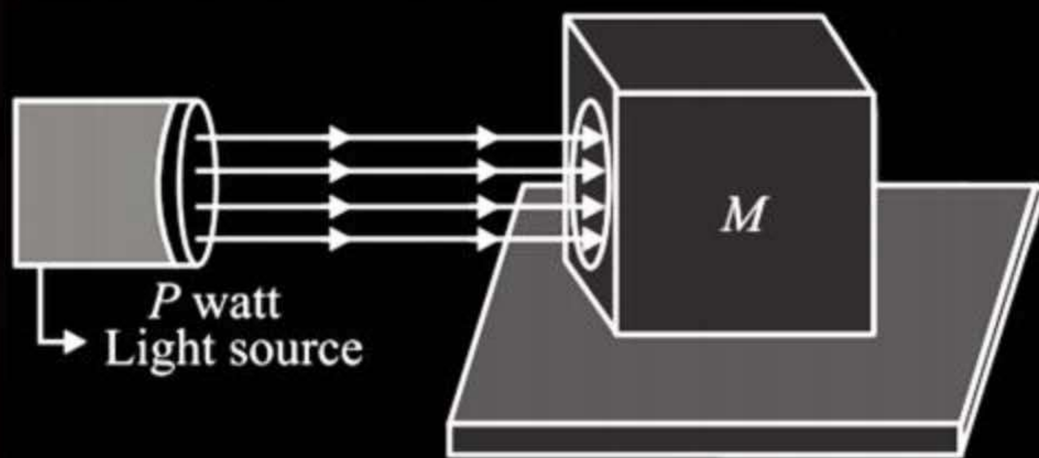
$T\sin\theta = \frac{2IA}{c}$

$T\cos\theta = mg$

$\tan\theta = \frac{2IA}{mgc}$

Q. A source of light of power P is shown in figure. Find the force on the block placed in the path of the light rays. The surface of body on which the light beam is incident is having a reflection coefficient $a_r = 0.7$ and absorption coefficient $a_a = 0.3$.

Ans : A



(A) $F = 1.7\ \mathrm{P/c}$

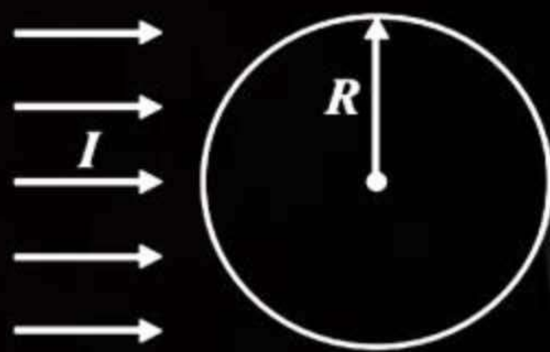
(B) $F = 2.7\ \mathrm{P/c}$

(C) $F = 1.2\ \mathrm{P/c}$

(D) $F = 1.6\ \mathrm{P/c}$

Q. Consider a sphere of radius R exposed to radiation of intensity I as shown in figure. If surface of sphere is partially reflection and reflection coefficient is 0.3, then radiation force experienced is

Ans : A



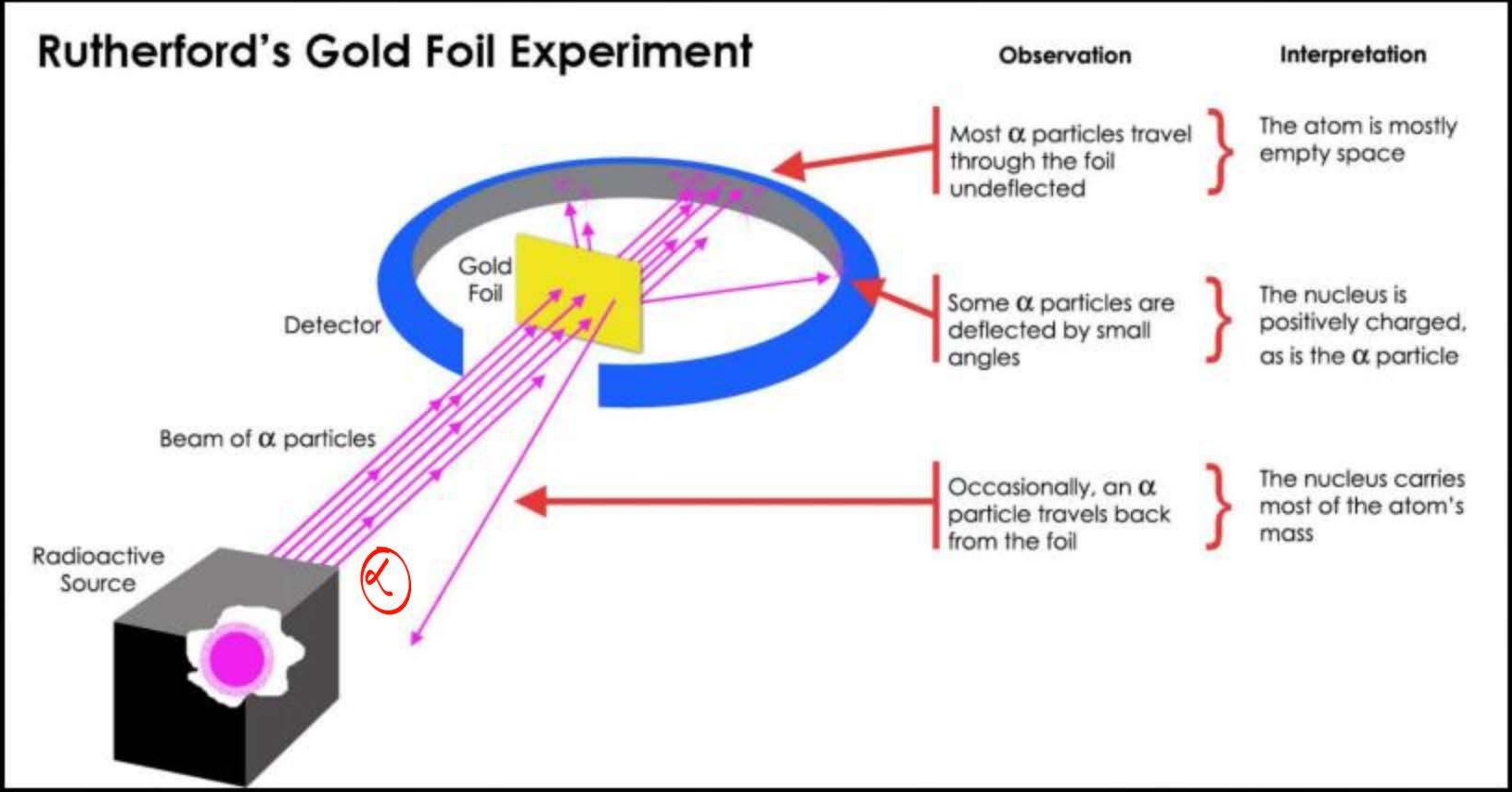
(A) $\dfrac{\pi R^2 I}{c}$

(B) $\dfrac{1.7\pi R^2 I}{c}$

(C) $\dfrac{1.3\pi R^2 I}{c}$

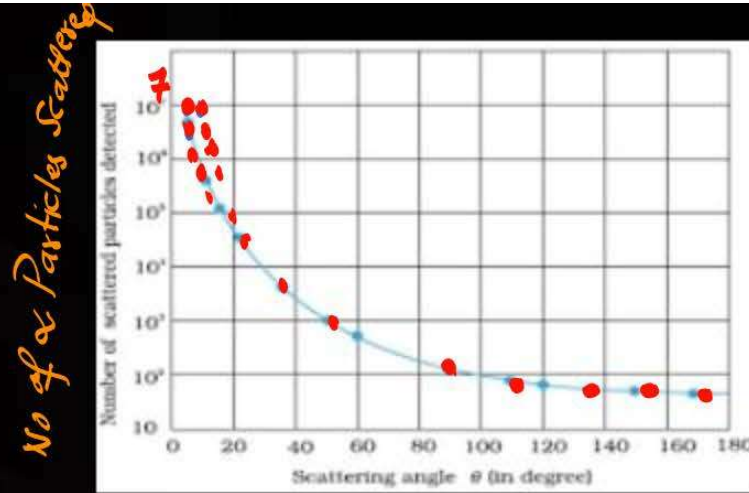
(D) None of these

Rutherford α particle scattering experiment



Drawbacks:

- Could not explain spectra
- Could not explain stability of atom



Application

❖ **Closest distance of approach:** (r_0)

$E_i = E_f$

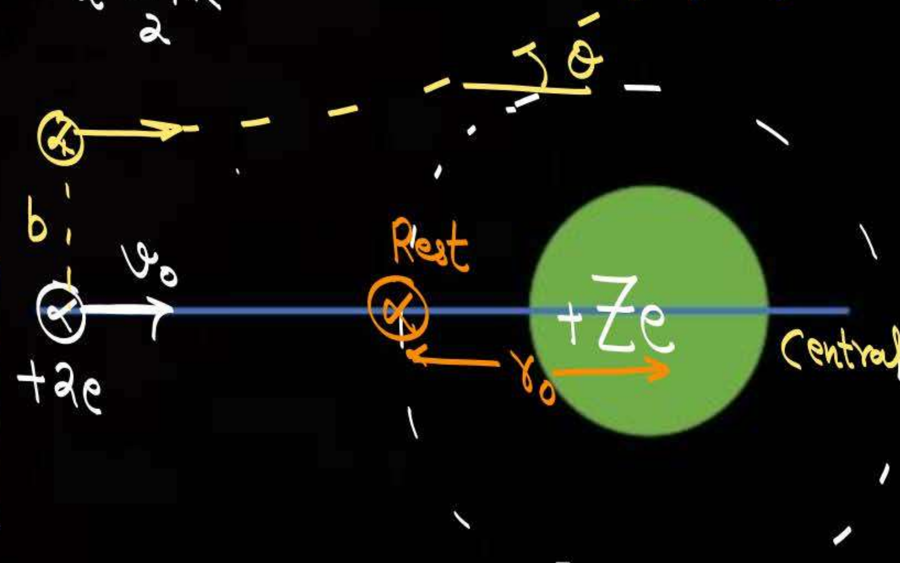
$\frac{1}{2}mv_0^2 = \frac{K(2e)(Ze)}{r_0}$

❖ **Impact parameter:** $\boxed{b = \frac{KZe^2 \cot(\theta/2)}{KE_\alpha}}$

$b\uparrow$ Scattering$\downarrow$

$b\downarrow$ Scattering$\uparrow$

$\alpha = {}_2He^{4++}$



Bohr's Model

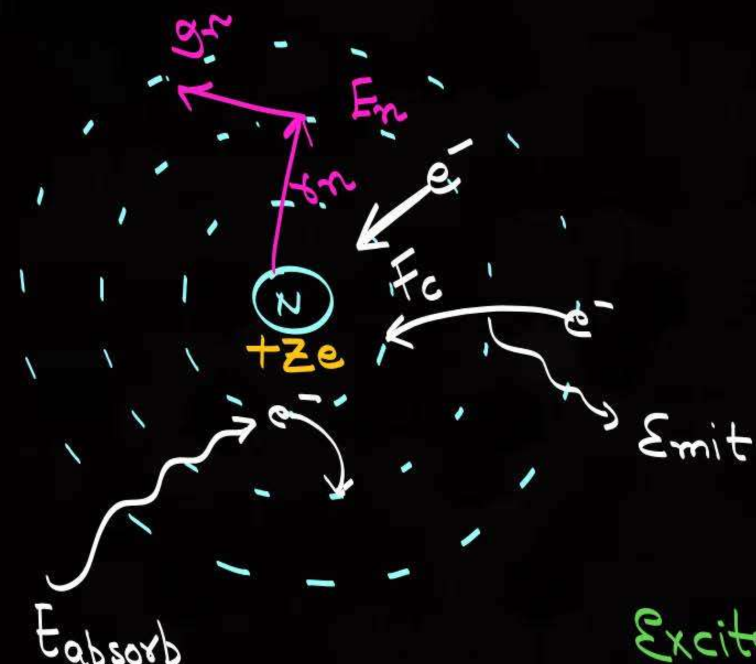
Postulates

1. $F_{col} = \frac{mv^2}{r}$

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

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

3. de-excitation or Excitation $\boxed{\Delta E = |E_f - E_i|}$



Z → Atomic no

⇓

no of protons

⇓

charge = +e

Nucleus ⇒ Protons

Total charge = +Ze

Excitation or de-excitation fix Energy is either absorb or Relase.

$$E_{fix} = \frac{hc}{\lambda_{fix}}$$

1. $\boxed{r_n = \frac{a_0 n^2}{Z}}$

$a_0 = 0.529\,\mathring{A}$

2. $\boxed{v_n = v_0 \frac{Z}{n}}$

$v_0 = 2.2 \times 10^6$ m/s

3. $E_n = -\frac{2\pi^2 m e^4 K^2 Z^2}{n^2 h^2}$

$\boxed{E_n = -13.6 \frac{Z^2}{n^2} eV}$

- Time Period of any orbit = $T = \frac{2\pi r_n}{v_n}$

$T \propto \frac{r_n}{v_n}$

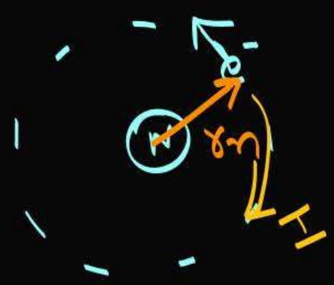
$T \propto \frac{n^2}{Z} \cdot \frac{n}{Z}$

$\boxed{T \propto \frac{n^3}{Z^2}}$

- freq in n^{th} orbit $\boxed{\nu \propto \frac{1}{T} \propto \frac{Z^2}{n^3}}$

- Current in n^{th} orbit $I = \frac{q}{t}$ $\quad I \propto \frac{1}{t}$ $\quad \boxed{I \propto \frac{Z^2}{n^3}}$

①



$A_n = \pi r_n^2$

$A_n \propto \frac{n^4}{Z^2}$

$I_n \propto \frac{Z^2}{n^3}$

$B = \frac{\mu_0 I_n}{2 r_n}$

$B \propto \frac{I_n}{r_n}$

$B \propto \frac{Z^2}{n^3} \cdot \frac{Z}{n^2}$

$\boxed{B \propto \frac{Z^3}{n^5}}$

$M_n = I \cdot A$

$M_n \propto \frac{Z^2}{n^3} \cdot \frac{n^4}{Z^2}$

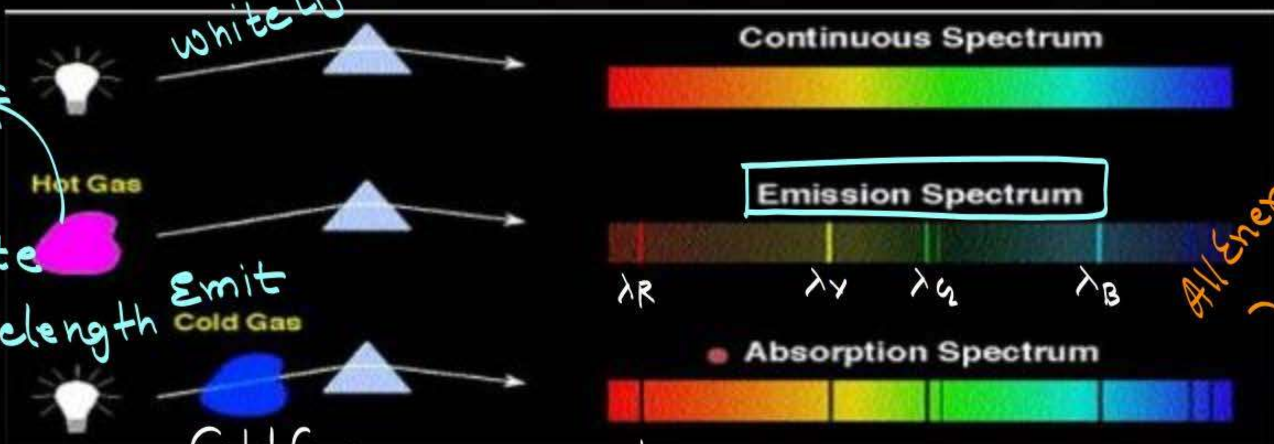
$\boxed{M_n \propto n}$

$\boxed{L \propto n}$

Ind of Z.

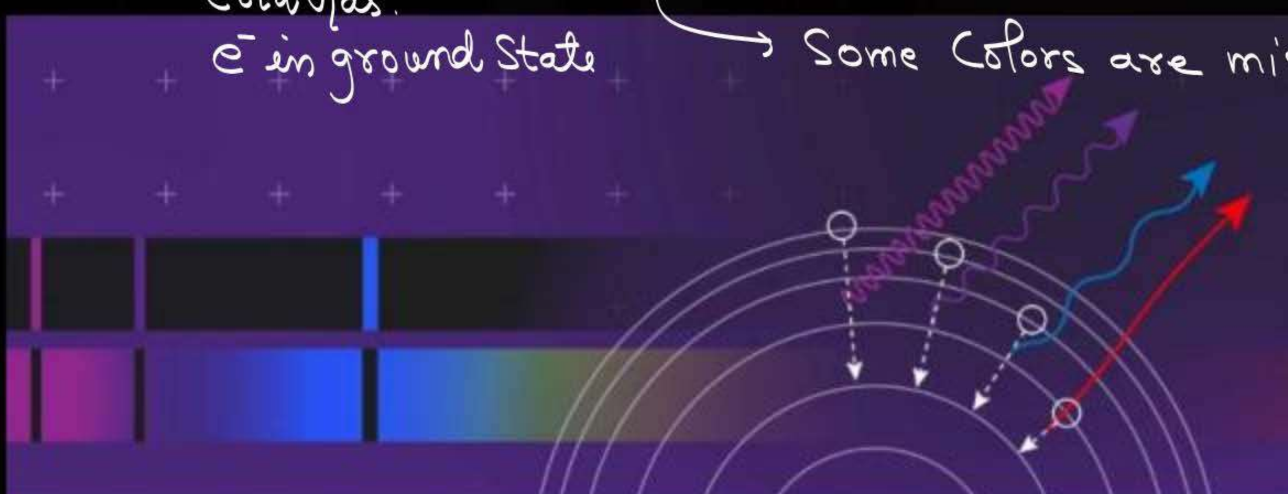
Spectral Series

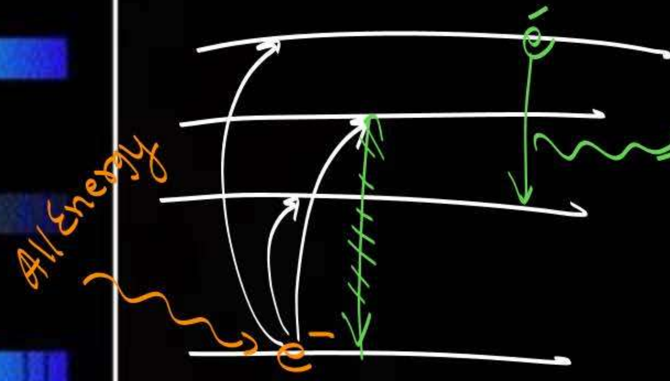
e^- excite
after
Some
de-excite
Emit
fix wavelength



Cold Gas.
e^- in ground State

Some Colors are missing

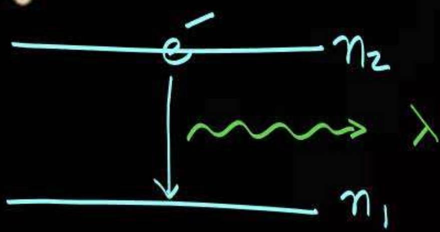




fix Energies
$\Downarrow$
absorb

$\lambda_{fix} \Rightarrow$ Missing.

Spectral Series

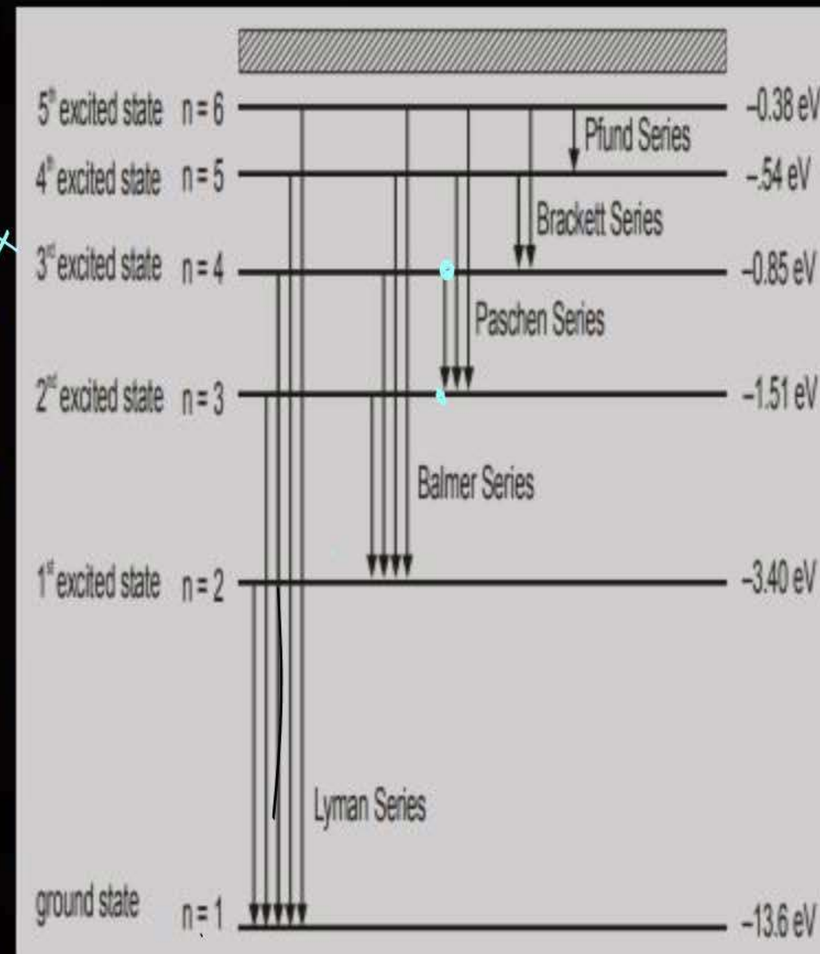


Rydberg Const. $109677\ cm^{-1}$

$$\frac{1}{\lambda} = R Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right]$$

n_1 = To which it is de-excit.
n_2 = from which it is de-ex
Z = atomic no

S.No	Spectral series Name	Region	n_1	n_2
1.	Lyman	UV	1	2, 3, 4 ..
2.	Balmer	Vis	2	3, 4, 5 ..
3.	Paschen	IR	3	4, 5, 6 ..
4.	Braket	IR	4	5, 6, 7 -
5.	Pfund	IR	5	6, 7, 8 --
6.	Humphery	Far IR	6	7, 8, 9 --



Other terminology used

1. Maximum and minimum wavelength in any series

λ_{max} for Paschen $n_1 = 3$, $n_2 = 4$

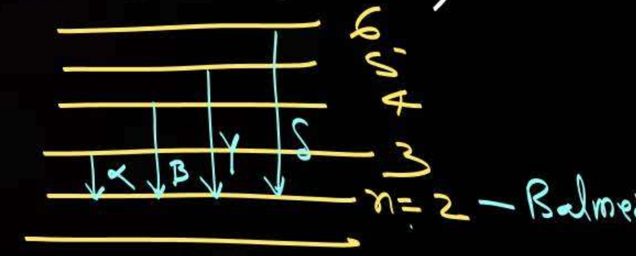
$\hookrightarrow E_{min}$

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

Concept λ_{max} n_1 = Series name $n_2 = n_1 + 1$

λ_{min} n_1 = Series name $n_2 = \infty$ (Series limit)

2. α, β, γ, δ Line in any series



$\lambda = ?$ δ line of Balmer. $n_1 = 2$

α Line $n_2 = n_1 + 1$ γ line $= n_1 + 3$

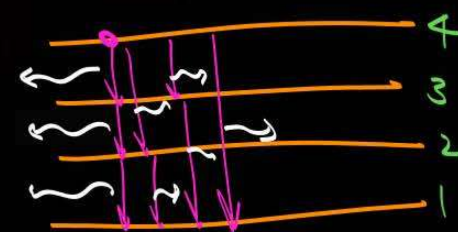
β Line $n_2 = n_1 + 2$ δ line $= n_1 + 4$.

3. No of spectral lines emitted

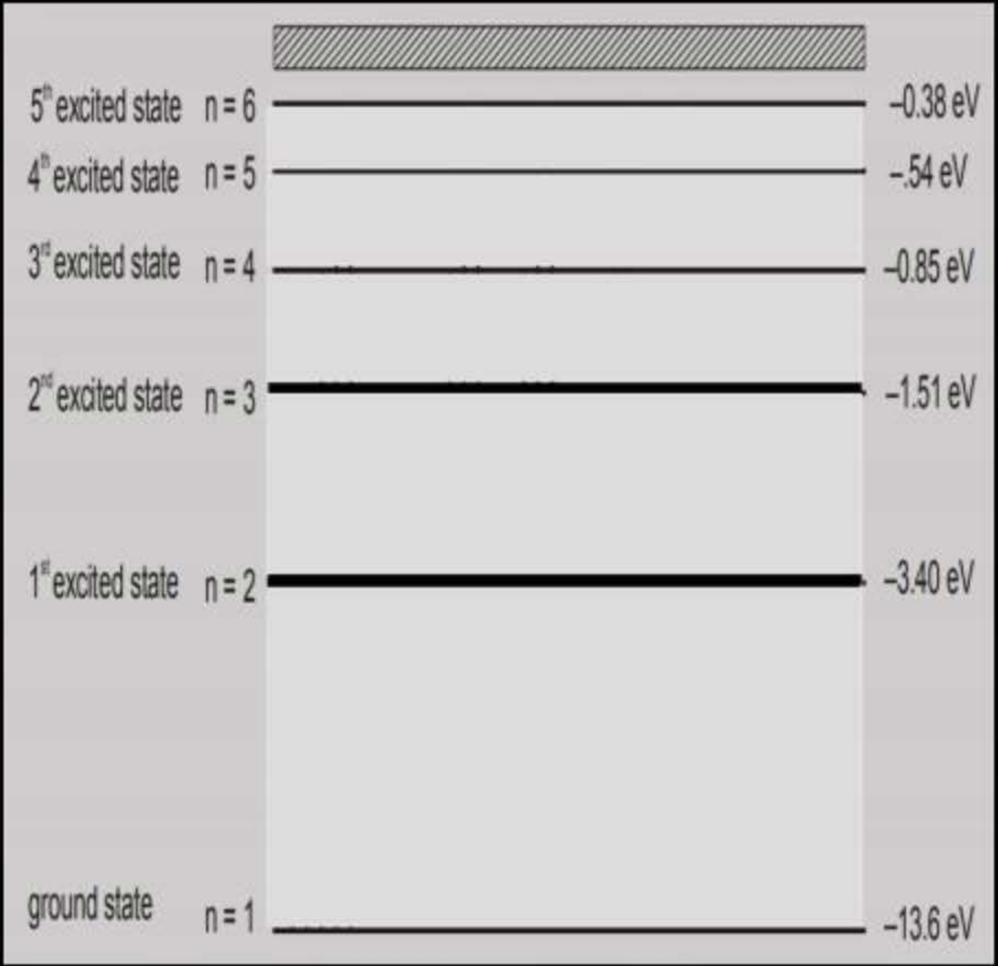
$n_2 \rightarrow n_1$

(de-excitation)

$$\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$



Excitation and Ionization potential



Drawbacks of Bohr's model

- This model could not explain the fine structure of spectral lines
- There was splitting of spectral lines in presence of magnetic field and electric field which could not be explained by Bohr's model.
- This model is only valid for single electron atoms (1e⁻ Should be there)
- This model is based on circular orbits of electron but in reality there are no circular orbits.
- This model could not explain the intensity of spectral lines
- This model only considered particle nature of electron.

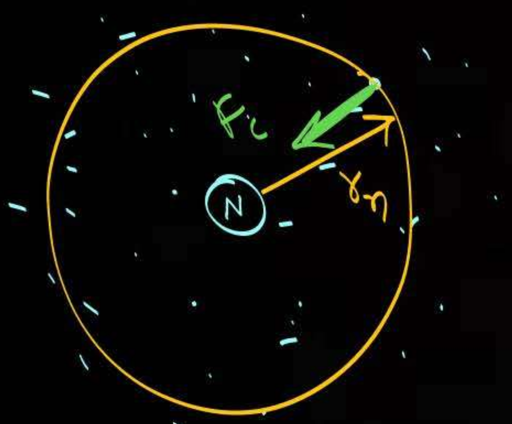
Q. A particle of mass m moves in a circular orbit in a central potential field $U(r) = U_0 r^4$. If Bohr's quantization conditions are applied, radii of possible orbitals r_n vary with $n^{\frac{1}{\alpha}}$, where α is 3.

Imp

$r \propto n^{1/3}$

(Main 2021, 17 Mar II)

(Hypothetical Bohr atom)



$PE = U_0 r^4$

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

$$v = \frac{nh}{2\pi m r}$$

$$F_c = \left|\frac{dU}{dr}\right|$$

$$f_c = U_0 4 r^3$$

$$\boxed{\frac{mv^2}{r} = 4U_0 r^3}$$

$$mv^2 = 4U_0 r^4$$

$$m\left(\frac{n^2h^2}{4\pi^2 m^2 r^2}\right) = 4U_0 r^4$$

$n^2 \propto r^6$

$n^{2/6} \propto r$

$n^{1/3} \propto r$

Q. The electric potential between a proton and an electron is given by $V = V_0 \ln \frac{r}{r_0}$, where r_0 is a constant. assuming Bohr's model to be applicable, write variation of r_n with n, n being the principal quantum number. **[2003]**

Ans : A

HW

(A) $r_n \propto n$

(B) $r_n \propto \frac{1}{n}$

(C) $r_n \propto n^2$

(D) $r_n \propto \frac{1}{n^2}$

Q. A particle of mass m moves in a circular orbit in a central potential field $U(r) = \frac{1}{2}kr^2$. If Bohr's quantization conditions are applied, radii of possible orbitals and energy levels vary with quantum number n as **[Main 2019]**

HW

Ans : C

(A) $r_n \propto n, E_n \propto n$

(B) $r_n \propto n^2, E_n \propto \frac{1}{n^2}$

(C) $r_n \propto \sqrt{n}, E_n \propto n$

(D) $r_n \propto \sqrt{n}, E_n \propto \frac{1}{n}$

Q. A hydrogen atom, initially in the ground state is excited by absorbing a photon of wavelength 980 Å. The radius of the atom in the excited state in terms of Bohr radius a_0 will be (Take $hc = 12500$ eV-Å) **[Main 2019]**

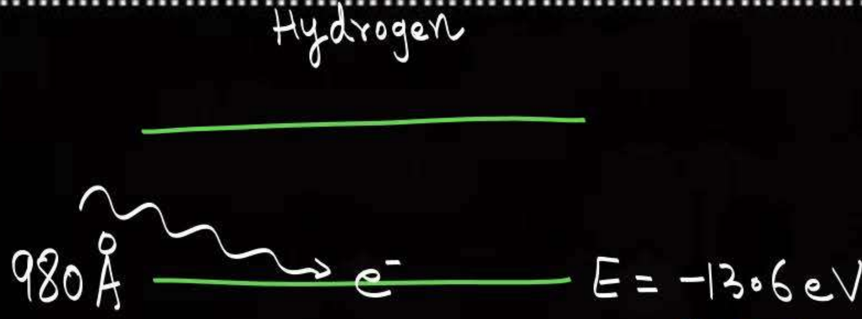
Ans : C

(A) $4a_0$

(B) $9a_0$

(C) $16a_0$

(D) $25a_0$

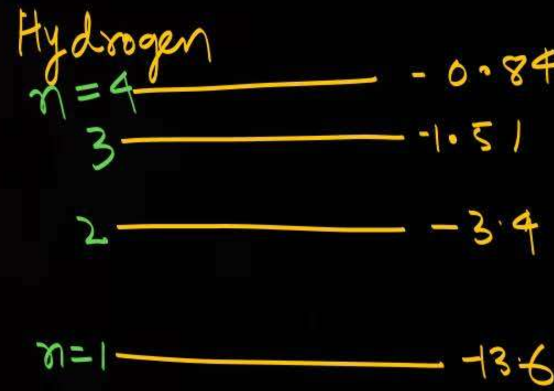


$+12.7$ eV

-0.84 eV

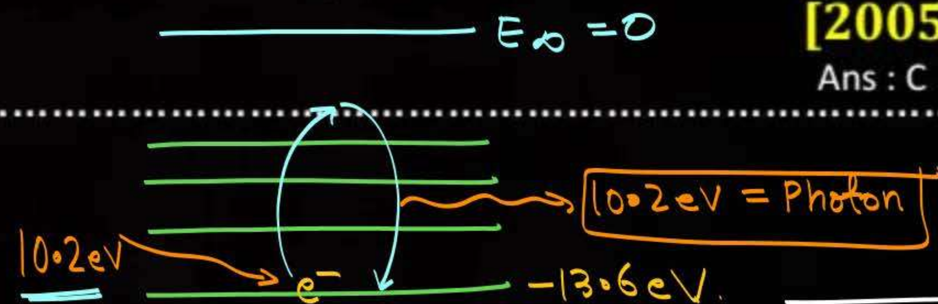
Ans $E_i = \frac{12500}{980}$ eV $= 12.7$ eV

$r_n = a_0 \frac{n^2}{Z} = a_0 16.$



Q. A photon collides with a stationary hydrogen atom in ground state inelastically. Energy of the colliding photon is 10.2 eV. After a time interval of the order of micro second another photon collides with same hydrogen atom inelastically with an energy of 15 eV. What will be observed by the detector? **[2005]**

Ans : C



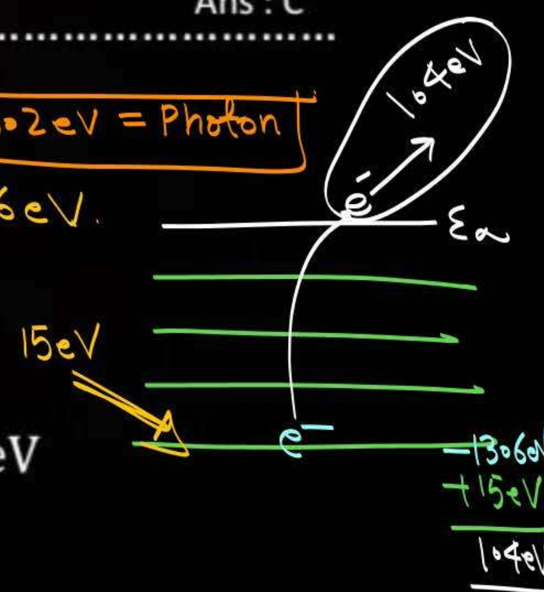
(A) 2 photons of energy 10.2 eV

(B) 2 photons of energy 1.4 eV

(C) One photon of energy 10.2 eV and an electron of energy 1.4 eV

Ans

(D) One photon of energy 10.2 eV and another photon of energy 1.4 eV



Q. The electron in a hydrogen atom first jumps from the third excited state to the second excited state and subsequently to the first excited state. The ratio of the respective wavelengths λ_1/λ_2 of the photons emitted in this process is

[Main 2019]

Ans : D

A. 20/7

B. 27/5

C. 7/5

D. 9/7

Q. In a hydrogen like atom electron makes transition from an energy level with quantum number n to another with quantum number (n –1). If n >> 1, the frequency of radiation emitted is proportional to **(2013 Main)**

Ans : D

(A) 1/n

(B) $1/n^2$

(C) $1/n^4$

(D) $1/n^3$

Ans

$n = \infty$

$\nu =$ n

$n = 2$

$n = 1$

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

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

$$\nu \propto \left[\frac{1}{(n-1)^2} - \frac{1}{n^2}\right]$$

$$\nu \propto \left[\frac{n^2 - (n-1)^2}{n^2(n-1)^2}\right]$$

$$\propto \left[\frac{\cancel{n^2} - \cancel{n^2} - \cancel{1} + 2n}{n^2(n - \cancel{1})^2}\right] \propto \frac{2n}{n^4}$$

$$\boxed{\nu \propto \frac{1}{n^3}}$$

Q. A He^{+} ion is in its first excited state. Its ionization energy is **[Main 2019]**

Ans :B

(A) 54.40 eV

(B) 13.60 eV

(C) 48.36 eV

(D) 6.04 eV

Q. In Li^{++}, electron in first Bohr orbit is excited to a level by a radiation of wavelength λ. When the ion gets de-excited to the ground state in all possible ways (including intermediate emissions), a total of six spectral lines are observed. What is the value of λ? **[Main 2019]**

[Take, $h = 6.63 \times 10^{-34}$ Js; $c = 3 \times 10^{8}$ ms^{-1}]

Ans : C

A 9.4 nm

B 12.3 nm

C 10.8 nm

D 11.4 nm

Q. Imagine that the electron in a hydrogen atom is replaced by a muon (μ). The mass of muon particle is 207 times that of an electron and charge is equal to the charge of an electron. The ionization potential of this hydrogen atom will be ______.

(Main 2021, 18 Mar I)

Ans : B

A 13.6 eV

B 2815.2 eV

C 331.2 eV

D 27.2 eV

Nucleus and Nucleons

(no of P + no of n) = (Mass no)

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

X: Symbol of Element

Z: At. no (no of Protons)

- Radius of nuclei

$$\boxed{R = R_0 A^{1/3} \qquad R_0 = 1.2\ fm = 1.2\times10^{-15}\ m}$$

- Volume of Nuclei

$$V = \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R_0^3 A \qquad \boxed{V \propto A}$$

- Density of nuclei

$$D = \frac{M_{Nucleus}}{V_{nucleus}} = \frac{\cancel{A} m_0}{\frac{4}{3}\pi R_0^3 \cancel{A}} = \frac{3m_0}{4\pi R_0^3} = Const$$

$$\approx 10^{17}\ Kg/m^3$$

A = Mass no.

$m_p \approx m_n \approx m_0$ (avg value)

$M_{nucleus} = A m_0$

Particle	Mass in Kg	Mass in amu
Electron	9.11×10^{-31} Kg	0.00055 amu
Proton	1.6725×10^{-27} Kg	1.0072 amu
Neutron	1.675×10^{-27} Kg	1.0086 amu

Nuclear Force

- Range of force: (order of few fermi) ($10^{-15}m$)
- Nature of force: attractive
  Repulsive.
- Strength of force $f_a \propto \frac{1}{r^7}$
  $F_r \propto \frac{1}{r^9}$.
- Independence of charge $p \leftrightarrow p$ $p \leftrightarrow n$.
  $n \leftrightarrow n$
- Spin dependence:
  Same spin $(F_a \text{ or } F_r)\uparrow$
  opp spin $(F_a \text{ or } F_r)\downarrow$.
- Non central force:
  Gravitational, EM $\Rightarrow$ Central force.
  Nuclear $\rightarrow$ Non-Central.
- Non conservative:
  Work done is Path dep.
- Position dependence:
  where nucleons are Present.

- I[st] order force: force of Interaction is limited to first Neighbours.

Nuclear stability

$Z < 20$

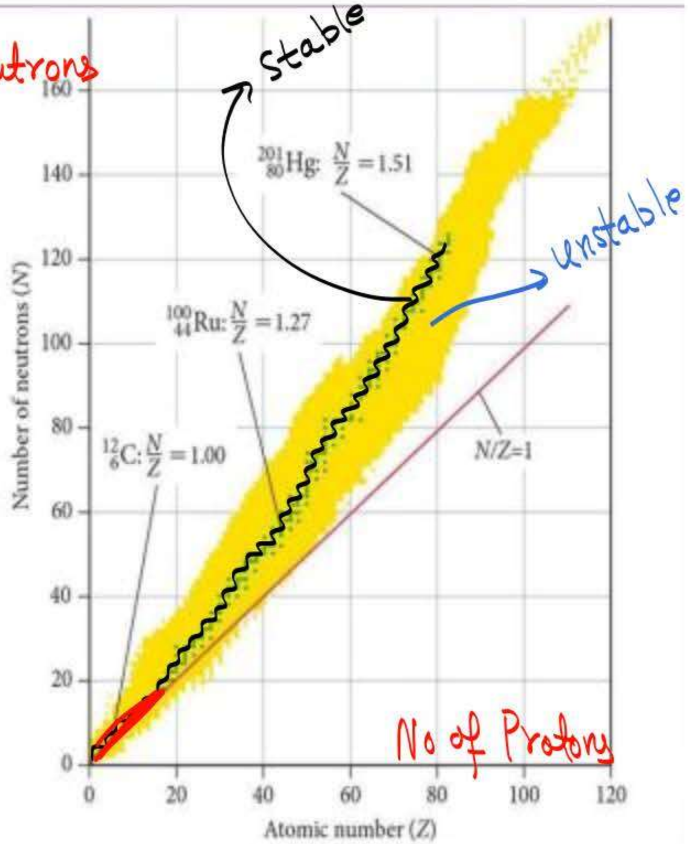
$\frac{N}{Z} = 1$

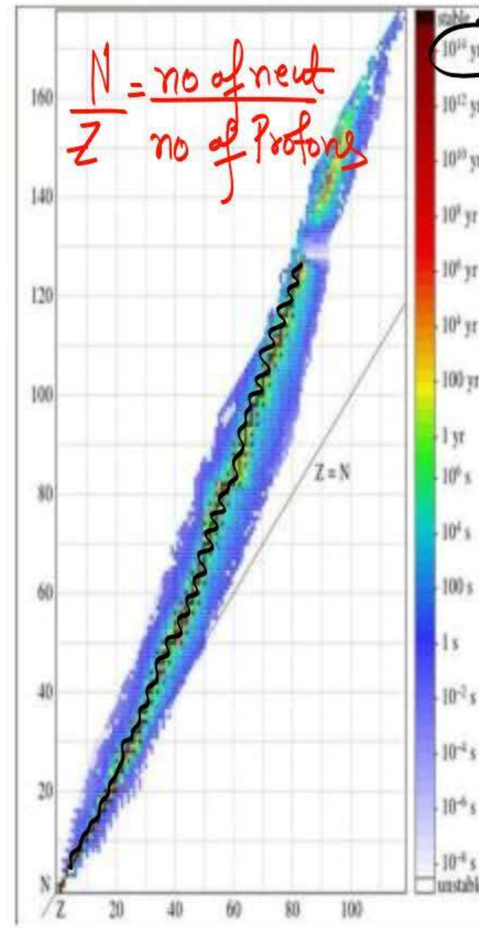
$20 < Z < 60$

$\frac{N}{Z} = 1.27$

$Z > 60$

$\boxed{\frac{N}{Z} = 1.51}$





NOTE:
The farther away a nuclide is from the valley of stability, the shorter its half life.

"Farther = less (kinetically) stable"

Einstein Energy mass Relation and Mass defect

$$\boxed{E = mc^2}$$

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

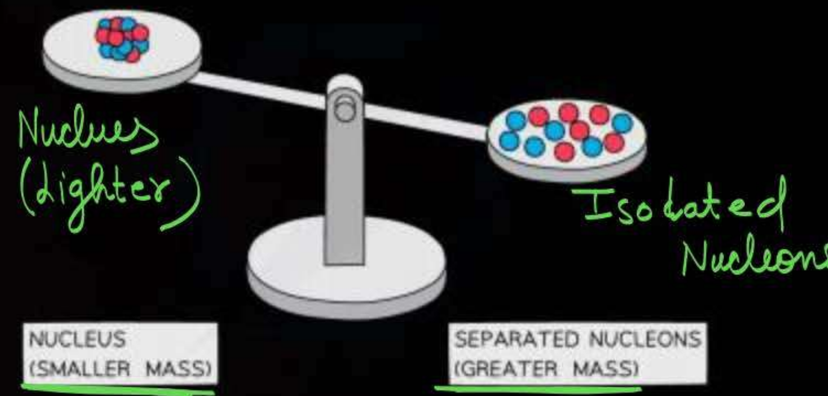
no of Protons $= Z$

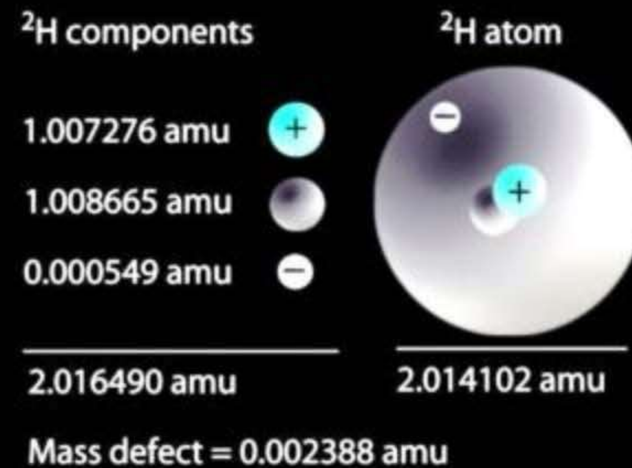
no of neutrons $= (A-Z)$

$$m_{\text{nucleus Theo}} = Zm_p + (A-Z)m_n$$

$$m_{exp} = m_N.$$

$$\text{mass defect} = \left(Zm_p + (A-Z)m_n - m_{Nuc}\right)$$





$$B.E = \Delta m\, c^2$$

$$\boxed{B.E = \left[Zm_p + (A-Z)m_n - m_{Nucl}\right]c^2}$$

* $$\frac{BE}{\text{Nucleon}} = \frac{BE}{A} = \frac{\left[Zm_p + (A-Z)m_n - m_{Nucl}\right]c^2}{A}$$

Better Parameter

to determine nuclear stability

Binding energy per nucleon and its significance

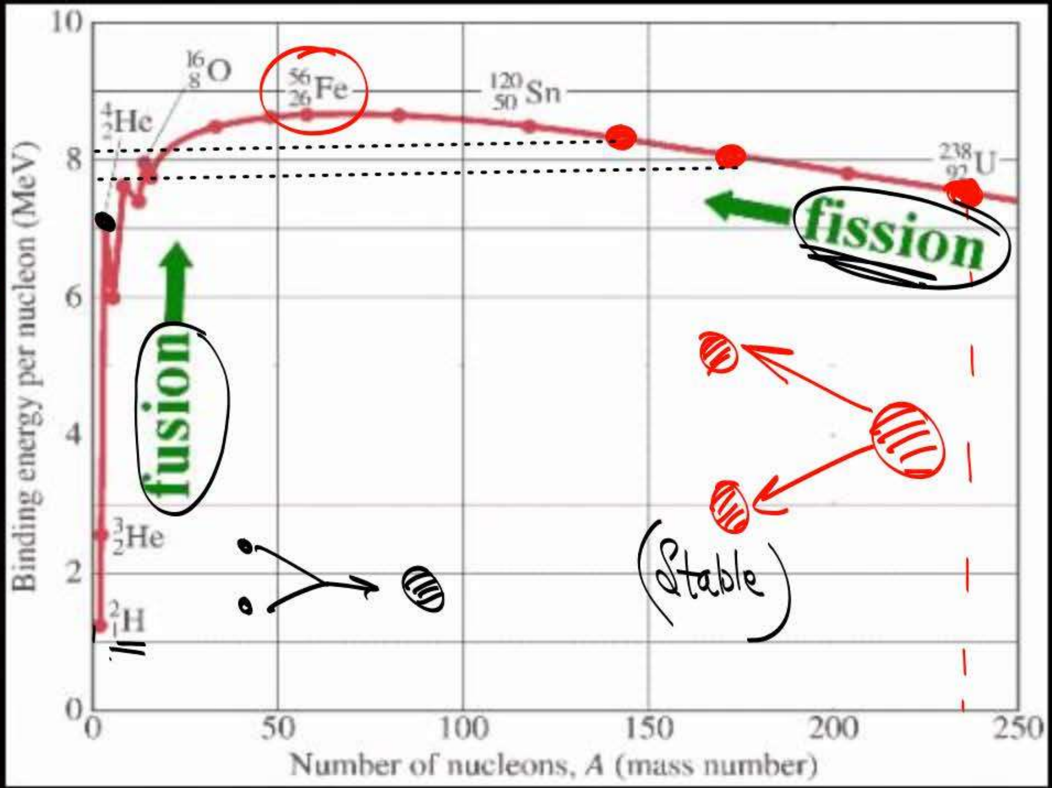
Binding energy of iron is 492.8 MeV and bismuth is 1640 MeV.
Which nucleus is more stable? (A(Fe)=56, A(Bi)=209

$BE_{Fe} = 492.8$ MeV

$BE_{Bi} = 1640$ MeV.

$\left.\frac{BE}{A}\right|_{Fe} = \frac{492.8}{56} = 8.8$ MeV (Stable)

$\left.\frac{BE}{A}\right|_{Bi} = \frac{1640}{209} = 7.84$ MeV



Q.

Find binding Energy of an alpha particle from following data:

Mass of helium nucleus: 4.001265amu

Mass of proton: 1.007277amu

Mass of Neutron: 1.00866amu

(take 1 amu = 931.4813Mev)

Whenever Que mass = amu.

$E = (\Delta m)\, 931.5\ MeV.$

$\boxed{1\ amu = 931.5\ MeV}$

* when Mass in Kg

$E = \Delta m c^2$

${}_2He^4$

2 proton $m_p = 1.007277\ u$

2 Neutron $m_N = 1.00866\ u.$

$m_{nucl} = 4.001265\ amu$

Theoretically $m_{Nucl} = 2m_p + 2m_N$

$= 2.014554 + 2.017332$

$= 4.031886\ u.$

$m_{Nucleus\ actual} = 4.001265\ u.$

$\boxed{BE = \Delta m c^2 = 28.52\ MeV}$

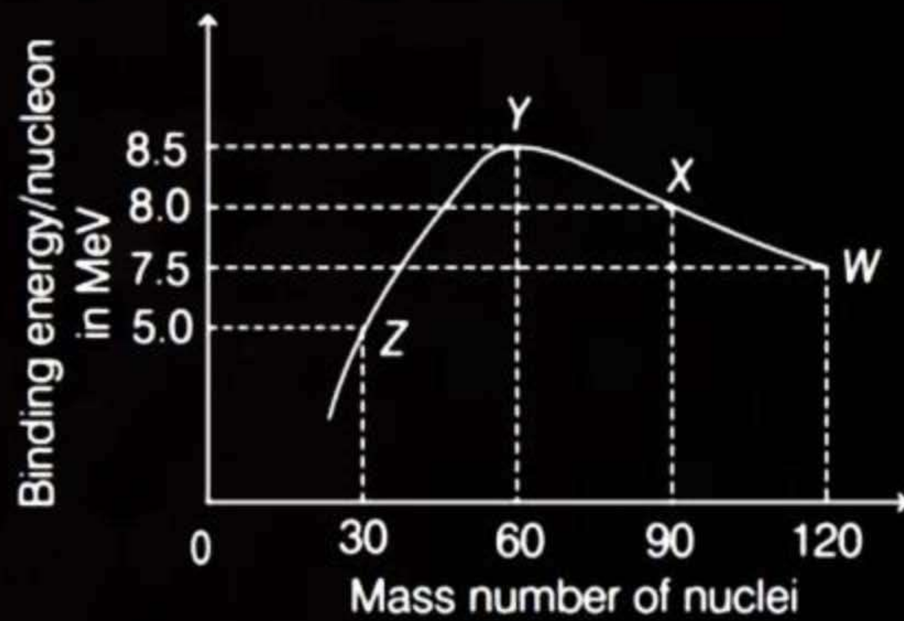
Q. Binding energy per nucleon versus mass number curve for nuclei is shown in figure. W, X, Y and Z are four nuclei indicated on the curve. The process that would release energy is **(1999)**

(A) $Y \rightarrow 2Z$

(B) $W \rightarrow X + Z$

(C) $W \rightarrow 2Y$

(D) $X \rightarrow Y + Z$



Q-Value of Nuclear Reaction

Q-value of a nuclear reaction is defined as the difference in the rest mass energies of particle and nuclei before reaction and those of products formed after reaction. For example in a nuclear reaction.

$$A + B \rightarrow C + D$$

The Q-value of above reaction is defined as

$$Q = (m_A + m_B - m_C - m_D)c^2$$

$${}^{A_1}_{Z_1}A + {}^{A_2}_{Z_2}B \longrightarrow {}^{A_3}_{Z_3}C + {}^{A_4}_{Z_4}D + Q$$

$$\boxed{\begin{array}{l} Z_1 + Z_2 = Z_3 + Z_4 \\ A_1 + A_2 = A_3 + A_4 \end{array}}$$

$$\boxed{\begin{array}{l} Q \text{ value} = (m_{R_{nuc}} - m_{P_{nucl}})c^2 \\ \quad = BE_P - BE_R \end{array}}$$

Radioactivity

Spontaneous decay of Nuclei.

Measurement of Radioactivity

- 1 bequeral = 1 Bq = 1 disintegration/sec
- 1 Ci = 3.7×10^{10} dis/sec
- 1 Ru = 10^6 dis/sec

Fundamental Laws of Radioactivity

(1) Radioactivity is purely a nuclear process, it is not concerned in any manner with the extranuclear part of atom.

(2) As radioactivity is a nuclear process, it is independent from any chemical property of the element. As we've discussed.

(3) Radioactivity is a random process, its study is only possible by laws of probability, which one will disintegrate first is just a matter of chance.

(4) As radioactivity is a random process, the disintegration density throughout the volume of a radioactive element remains constant. If an element X decays to a daughter nuclide Y then in a given volume of element, all portions of volume will have same ratio of number of atoms of Y to that of X.

Radioactive Decay Law

"The activity of a radioactive element at any instant is directly proportional to the number of undecayed active atoms (parent atoms) present at that instant."

$t = 0$

N_0

(Initial)

$t = t$

N

(Left over)

Activity $= A =$ Rate of disin $= -\dfrac{dN}{dt}$

$$\boxed{A = \lambda N}$$

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

λ = disintegration Const.

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

OR

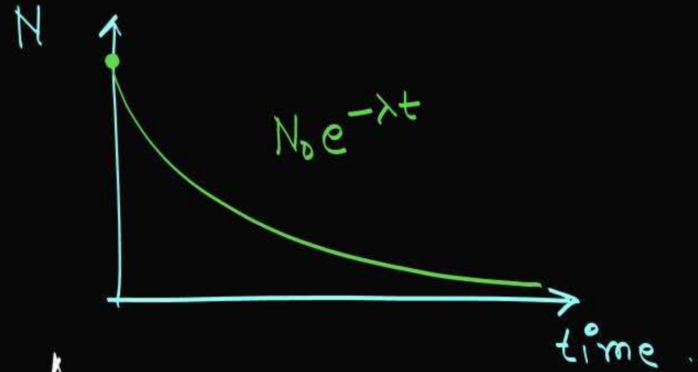
$$\boxed{N = N_0 2^{-t/T_{1/2}}}$$

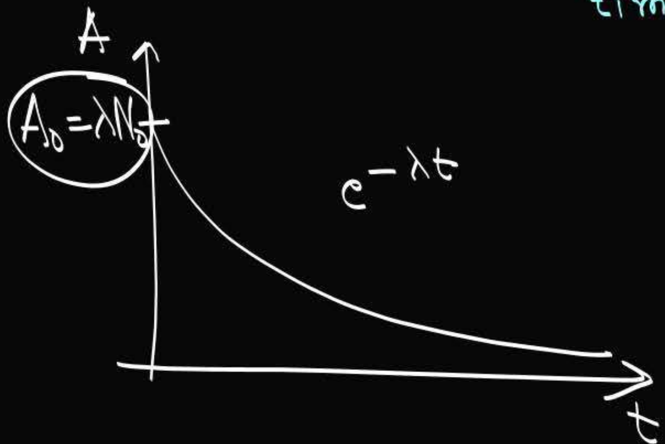
$t = 0 \quad A_0 = \lambda N_0$

$t = t \quad A = \lambda N$

$$\boxed{A = A_0 e^{-\lambda t}} \quad \text{OR} \quad \boxed{A = A_0 2^{-t/T_{1/2}}}$$

Imp points





No of Nuclei decayed.

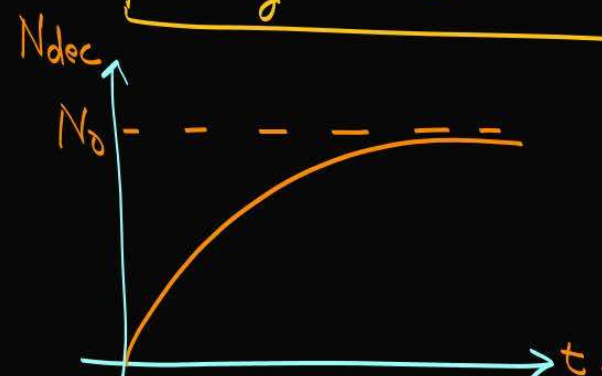
$t = 0 \quad N_0$

$t = t \quad N$

$$N_{decay} = N_0 - N$$

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

$$\boxed{N_{decay} = N_0 \left[1 - e^{-\lambda t}\right]}$$



Half Life

t at which $N_{left} = \frac{N_0}{2}$

$$\boxed{t_{1/2} = \frac{\ln 2}{\lambda}}$$

* $t = 0$ $\quad N_0$

$t = 1T_{1/2}$ $\quad \frac{N_0}{2}$

$t = 2T_{1/2}$ $\quad \frac{1}{2}\left(\frac{N_0}{2}\right) = \frac{N_0}{2^2}$

⋮

$t = n$ Half life $\quad \boxed{L_{eff} = \frac{N_0}{2^n}}$

* Mean life :- $\boxed{t_{mean} = \frac{1}{\lambda}}$

Type of decays

(+ve)

Property	α Particles	β Particles	γ Particles
Consists of	Nuclei of Helium	Electrons	Electromagnetic radiations
Charge	+2 charge	-1 unit charge	No charge
Mass	4 amu mass	Negligible mass	No mass
Affect of electric and magnetic field	Slightly affected	Strongly affected	Unaffected
Power of penetration	Least	Penetrates through 5 mm of aluminium or 1 mm of lead	Penetrate 30 cm thick iron.

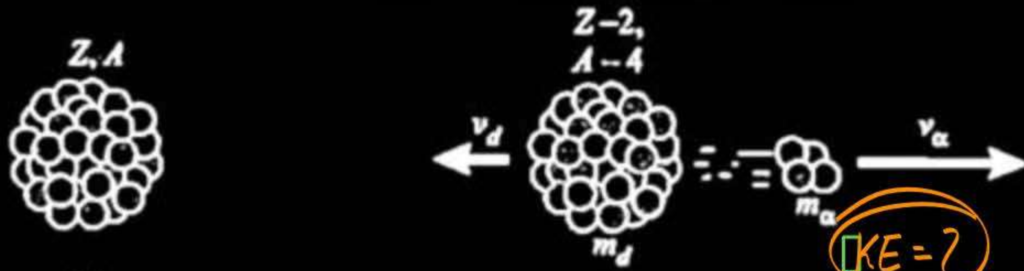
$_2He^{4++}$

β^+ $\left({}_{+1}e^0 + \nu\right)$

β^- $\left({}_{-1}e^0 + \bar{\nu}\right)$

(EM Radiation)

Alpha Decay



(a) (b)

KE = ?

$$\boxed{{}_{Z}X^{A} \xrightarrow[\alpha \text{ decay}]{} {}_{Z-2}Y^{A-4} + {}_{2}He^{4} + Q}$$

$$Q = (m_R - m_P)c^2$$

$$m_\alpha v_\alpha = m_y v_y \rightarrow v_y = \frac{m_\alpha v_\alpha}{m_y}$$

$$Q = \frac{1}{2} m_\alpha v_\alpha^2 + \frac{1}{2} m_y v_y^2$$

$$Q = \frac{1}{2} m_\alpha v_\alpha^2 + \frac{1}{2} \cancel{m_y} \frac{m_\alpha^2 v_\alpha^2}{m_y^{\cancel{2}}}$$

$$Q = \frac{1}{2} m_\alpha v_\alpha^2 \left[1 + \frac{m_\alpha}{m_y} \right]$$

$$Q = KE_\alpha \left[\frac{m_y + m_\alpha}{m_y} \right]$$

$$\boxed{Q = KE_\alpha \left[\frac{A}{A-4} \right]}$$

Beta Decay

Beta Minus Emission (β^-):

$n \rightarrow p + e^- + \bar{\nu}$

$${}_{Z}X^{A} \xrightarrow{\beta^-} {}_{Z+1}Y^{A} + {}_{-1}e^{0} + \bar{\nu}$$

$$\Delta E = (M_X - M_Y)\, C^2$$

Beta Plus Emission (β^+):

$p \rightarrow n + e^+ + \nu$

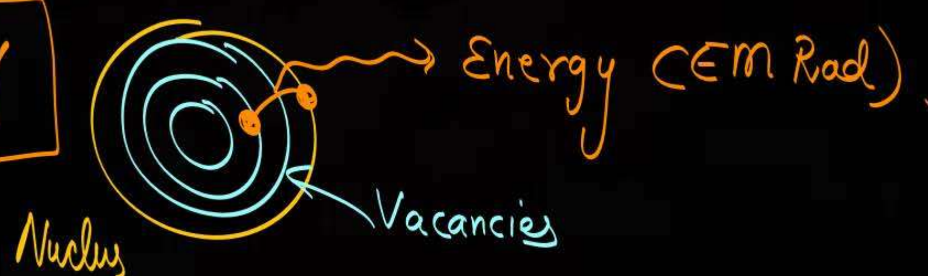
$${}_{Z}X^{A} \xrightarrow{\beta^+} {}_{Z-1}Y^{A} + {}_{+1}e^{0} + \nu$$

$$\Delta E = (M_X - M_Y - 2m_e)\, C^2$$

Gamma Decay

after α, β^+, β^- Sometimes nucles is in excited state.

$${}_{Z}X^{A*} \longrightarrow {}_{Z}X^{A} + \gamma$$



Q. In a radioactive decay chain, the initial nucleus is ${}^{232}_{90}Th$. At the end, there are 6α-particles and 4β-particles which are emitted. If the end nucleus is X, A and Z are given by **(Main 2019, 12 Jan II)**

Ans : B

(A) A = 202; Z = 80

(B) A = 208; Z = 82 Ans

(C) A = 200; Z = 81

(D) A = 208; Z = 80

$${}_{90}Th^{232} \longrightarrow {}_{Z}X^{A} + 6\,{}_{2}He^{4} + 4\,{}_{-1}e^{0}$$

$$232 = A + 24 + 4\times 0 \qquad A = 208$$

$$90 = Z + 12 - 4$$

$$82 = Z$$

Q. Using a nuclear counter, the count rate of emitted particles from a radioactive source is measured. At t = 0, it was 1600 counts per second and t = 8s, it was 100 counts per second. The count rate observed as counts per second at t = 6 s is close to **(Main 2019, 10 Jan I)**

Ans : B

(A) 400

(B) 200 Ans

(C) 150

(D) 360

$t = 0 \quad A = 1600 \ \frac{\text{Count}}{\text{sec}}$

$t = 6s$

$4T_{1/2} \quad t = 8\text{sec} \quad A = 100 \ \frac{\text{Count}}{\text{sec}}$

$T_{1/2} = 2\text{sec}$

n Half $\quad A \to \frac{A_0}{2^n}$ In this Ques $A \to \frac{1}{16}$

$n = 4$

$A = A_0 2^{-t/T_{1/2}}$

$100 = 1600\, 2^{-t/T_{1/2}}$

$\frac{1}{16} = 2^{-8/T_{1/2}}$

$16^{-1} = 2^{-8/T_{1/2}}$

$2^{-4} = 2^{-8/T_{1/2}}$

$4 = 8/T_{1/2} \quad T_{1/2} = 2\text{sec}$

$t = 0 \quad A = 1600$

$t = 2 \quad A = 800$

$t = 4s \quad A = 400$

$t = 6s \quad A = 200$

$t = 8s \quad A = 100$.

Q. In given time t = 0, Activity of two radioactive substances A and B are equal. After time t, the ratio of their activities $\frac{R_B}{R_A}$ decreases according to e^{-3t}. If the half life of A is In 2, the half-life of B will be

$T_{1/2A} = \frac{\ln 2}{\lambda_1}$ $\ln 2 = \frac{\ln 2}{\lambda_1}$ $\lambda_1 = 1$

(Main 2019, 9 Jan II)

Ans : B

(A) $4 \ln 2$

(B) $\frac{\ln 2}{4}$ Ans

(C) $\frac{\ln 2}{2}$

(D) $2 \ln 2$

	A	B
$t=0$	A_0	A_0
$t=$	R_A	R_B

$R_A = A_0 e^{-\lambda_1 t}$ $R_B = A_0 e^{-\lambda_2 t}$

$\frac{R_B}{R_A} = e^{-3t}$

$\frac{A_0 e^{-\lambda_2 t}}{A_0 e^{-\lambda_1 t}} = e^{-3t}$

$e^{(\lambda_1 - \lambda_2)t} = e^{-3t}$

$\lambda_1 - \lambda_2 = -3$

$1 - \lambda_2 = -3$

$4 = \lambda_2$

$4 = \lambda_2 = \frac{\ln 2}{T_{1/2B}}$

$T_{1/2} = \frac{\ln 2}{4}$

Q. After 280 days, the activity of a radioactive sample is 6000 dps. The activity reduces to 3000 dps after another 140 days. The initial activity of the sample in dps is **(2004, 2M)**

Ans : D

(A) 6000

(B) 9000

(C) 3000

(D) 24000 Ans

$t = 0$ A_0

140   $\frac{A_0}{2}$

280 days   6000 dps

280 + 140   3000 dps

$\frac{A_0}{4} = 6000$

$A_0 = 24{,}000$ dps

In 140 $\left(\frac{A}{2}\right)$

$T_{1/2} = 140$ days.

Q. A sample of radioactive material A, that has an activity of 10 mCi (1 Ci = 3.7×10^{10} decays/s) has twice the number of nuclei as another sample of a different radioactive material B which has an activity of 20 mCi. The correct choices for half-lives of A and B would, then be respectively

(Main 2019, 9 Jan I)

Ans : D

A 20 days and 10 days

B 5 days and 10 days

C 10 days and 40 days

D 20 days and 5 days

Q. A radioactive nucleus A with a half-life T, decays into a nucleus B. At $t = 0$, there is no nucleus B. After sometime t, the ratio of the number of B to that of A is 0.3. Then, t is given by **(2017 Main)**

Ans : A

A $t = T\dfrac{\log 1.3}{\log 2}$

B $t = T\log 1.3$

C $t = \dfrac{T}{\log 1.3}$

D $t = \dfrac{T\log 2}{\log 1.3}$

Q. Which of the following processes represent a γ-decay ? **(2002, 2M)**

Ans : C

(A) ${}^{A}X_{Z} + \gamma \rightarrow {}^{A}X_{Z-1} + a + b$

(B) ${}^{A}X_{Z} + {}^{1}n_{0} \rightarrow {}^{A-3}X_{Z-2} + c$

(C) ${}^{A}X_{Z} \rightarrow {}^{A}X_{Z} + f$

(D) ${}^{A}X_{Z} + e_{-1} \rightarrow {}^{A}X_{A-1} + g$

Q. The half-life of 215At is 100μs. The time taken for the activity of a sample of 215 At to decay to $1/16^{th}$ of its initial value is **(2002, 2M)**

Ans : A

(A) 400 μs

(B) 63 μs

(C) 40 μs

(D) 300 μs