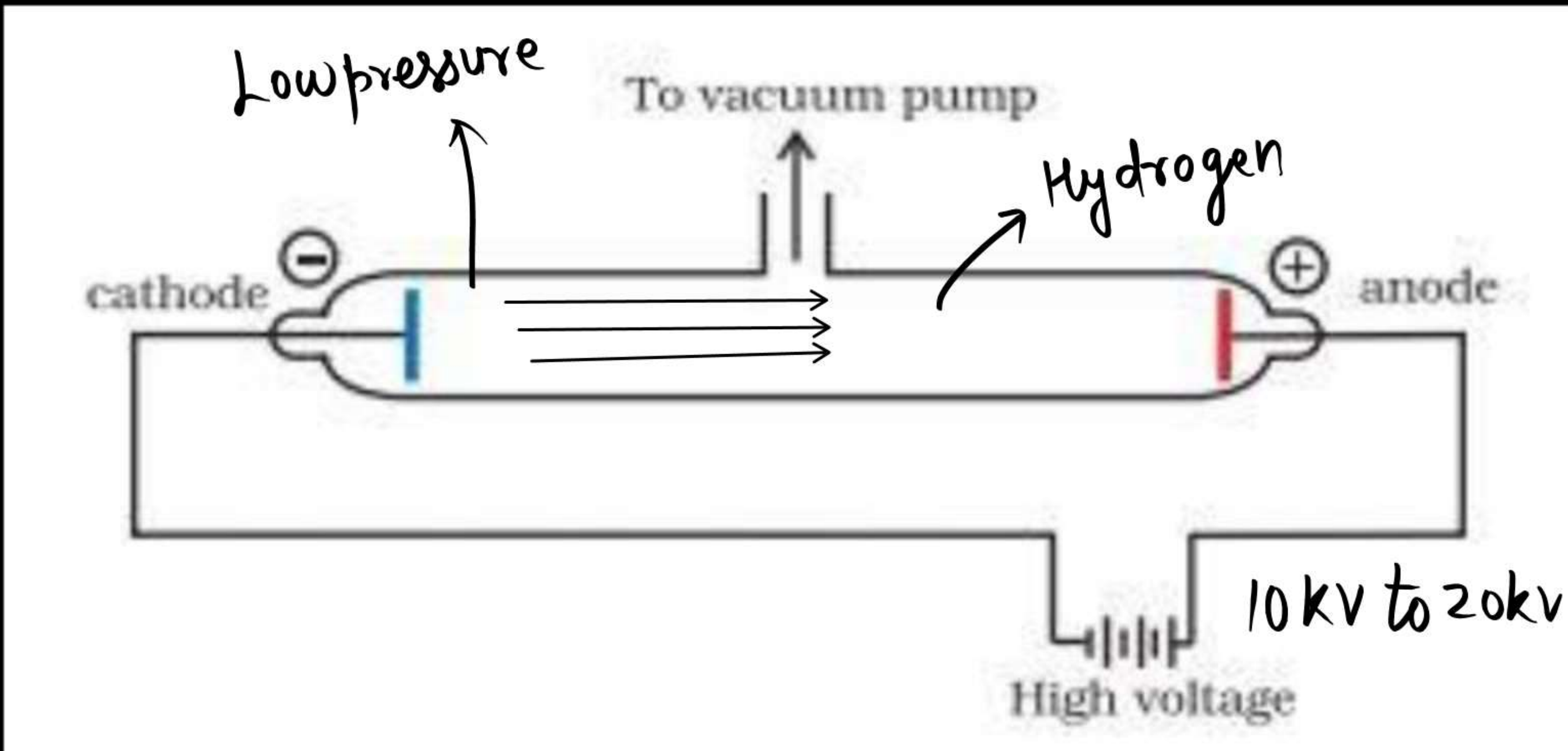
Atomic Structure

We will discuss internal structure of atom

Discovery of Fundamental particles

Discovery of Electron (Thomson)

C.R.T (cathode ray tube)



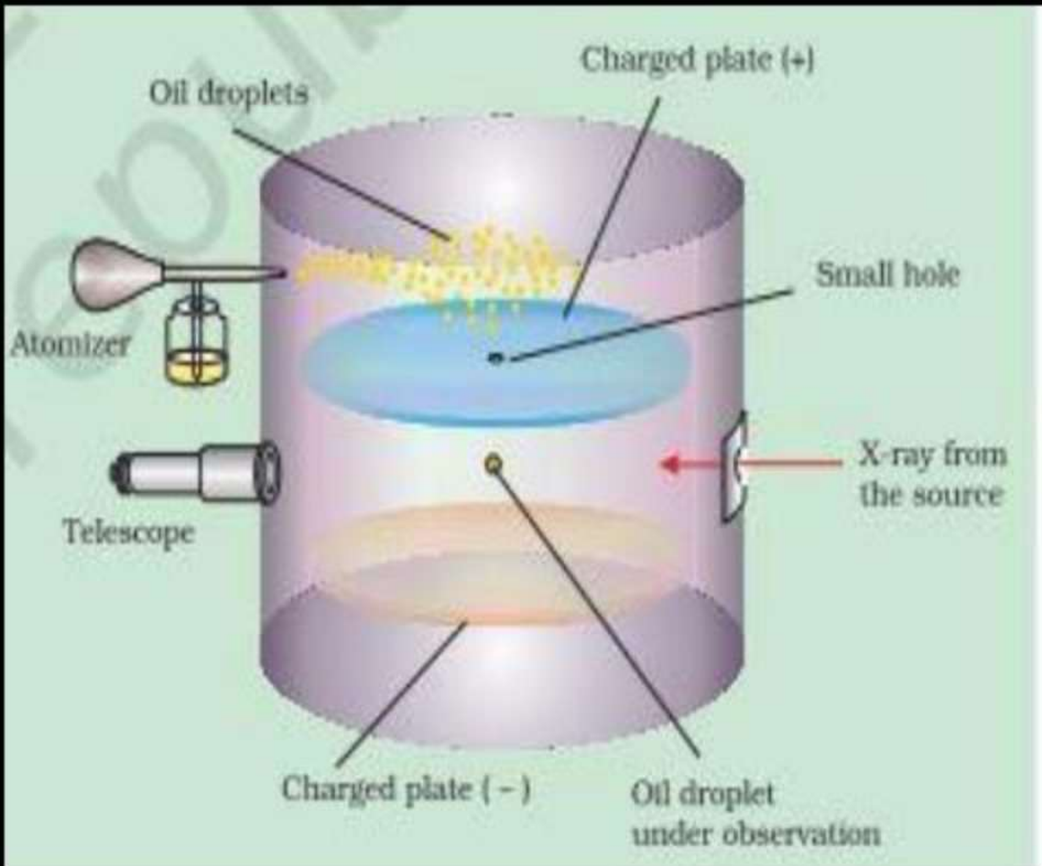
Charac of Cathode rays

1. C.R are travelled is straight line path
2. C.R are negatively charged
3. Possess some K.E
4. Produces heating effect
5. Deflected by MF

$$\frac{\text{charge}}{\text{mass}} = \frac{q}{m}$$

Sp. Charge of e is independent on nature of gas

Milliken oil drop experiment



charge of $e^{\ominus} = -1.6 \times 10^{-19}$ c

Millikan concluded that the magnitude of electrical charge, q, on the droplets is always an integral multiple of the electrical charge e, that is, q = n e, where n = 1, 2, 3... .

Calculation of charge and mass of e

1. Sp. Charge = $-1.75 \times 10^{8}\ \frac{c}{g}$

2. Charge on e = -1.6×10^{-19} C

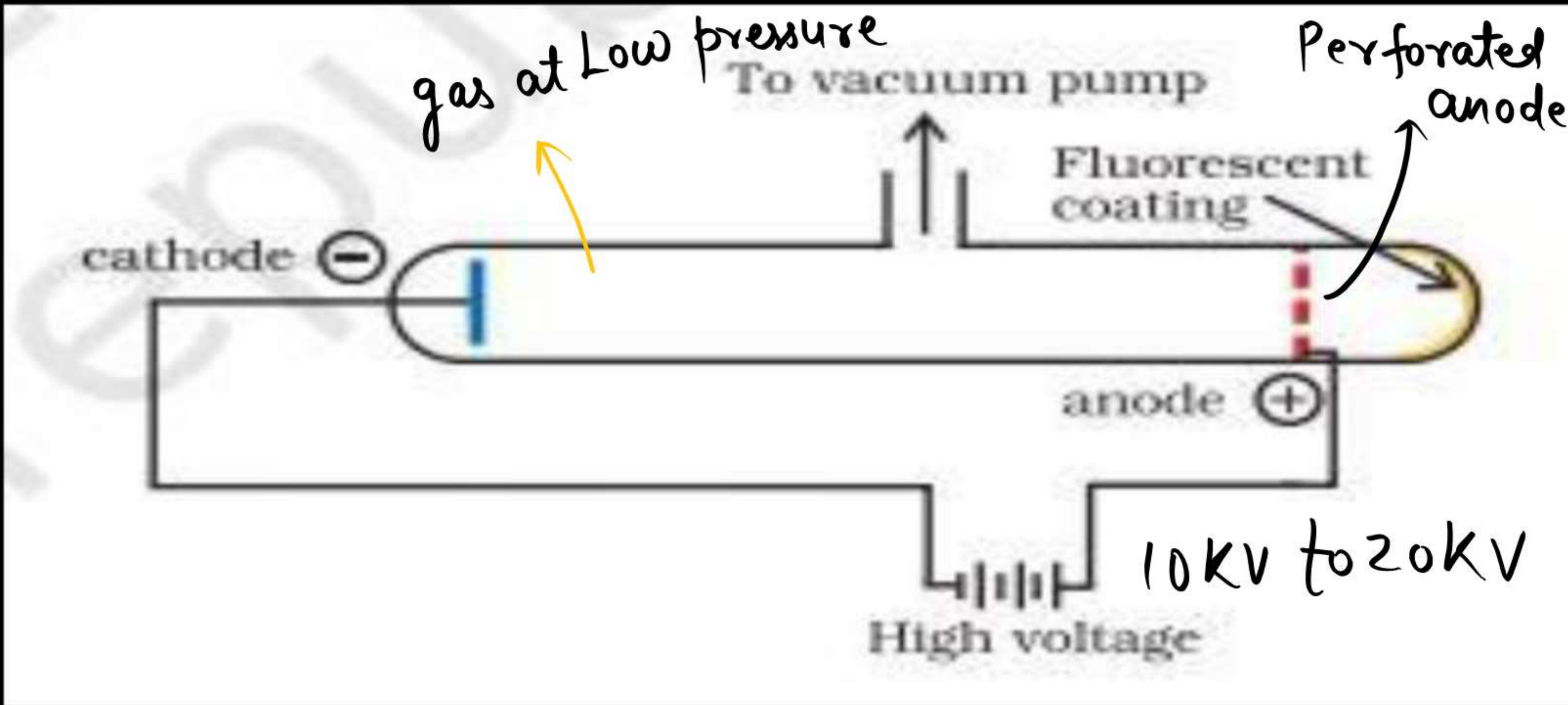
3. mass of e = 9.1×10^{-28} gm = 9.1×10^{-31} Kg

sp charge = $\frac{q}{m}$

$\left(m = \frac{q}{\text{sp charge}}\right)$

Discovery of proton [Goldstein]

Canal rays



Charac of anode rays (Canal rays)

1. Canal rays are travelled is straight line path
2. Possess some K.E
3. Produces heating effect
4. Deflected by MF
5. Canal rays are +vely charge

Sp. Charge of P is dependent on nature of gas

Charge and mass of proton

1. Sp. Charge = $\underbrace{9.58 \times 10^{4}} \frac{c}{g}$

2. Charge on P = $\underbrace{+1.6 \times 10^{-19}}$ C

3. mass of p = 1.6×10^{-24} gm = 1.6×10^{-27} Kg

Discovery of Neutron (chadwick)

$Po \longrightarrow \alpha$-particle

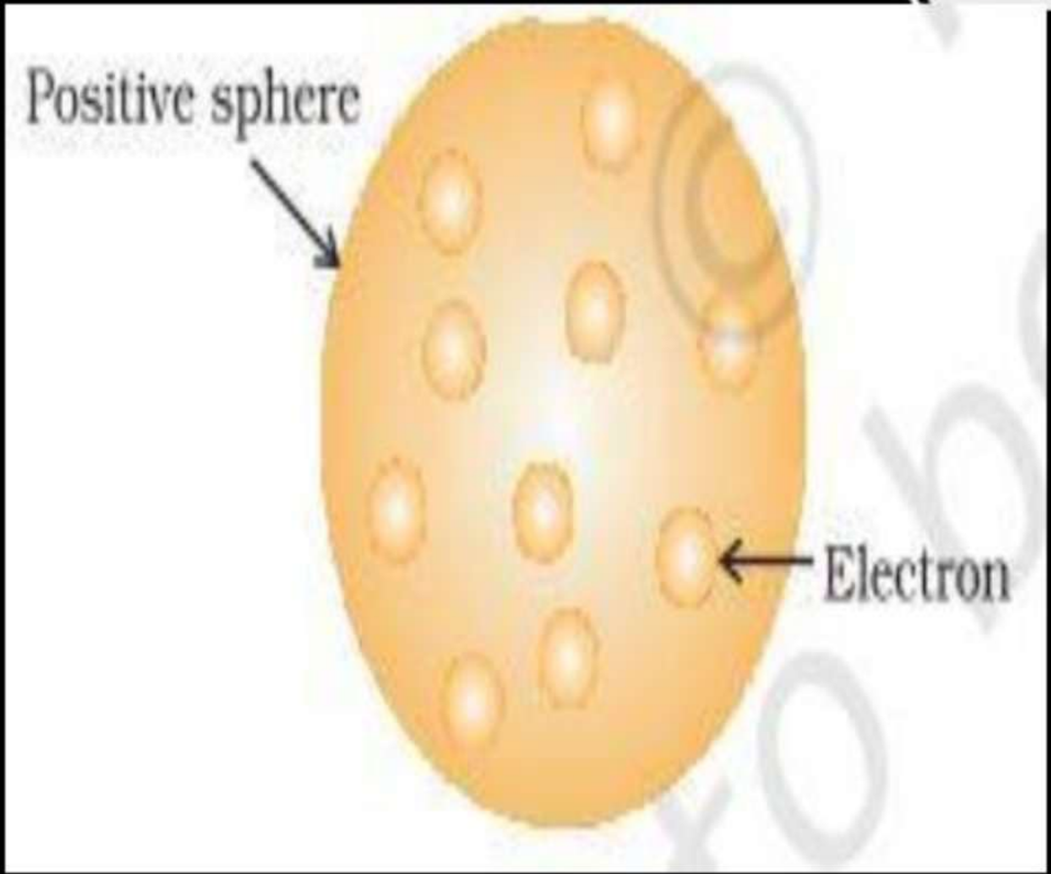
$$\boxed{{}_4Be^9 + {}_2He^4 \longrightarrow {}_6C^{12} + {}_0n^1}$$

Name	Symbol	Absolute charge/C	Relative charge	Mass/kg	Mass/u	Approx. mass/u
Electron	e	-1.6022×10^{-19}	-1	9.10939×10^{-31}	0.00054	0
Proton	p	$+1.6022\times10^{-19}$	+1	1.67262×10^{-27}	1.00727	1
Neutron	n	0	0	1.67493×10^{-27}	1.00867	1

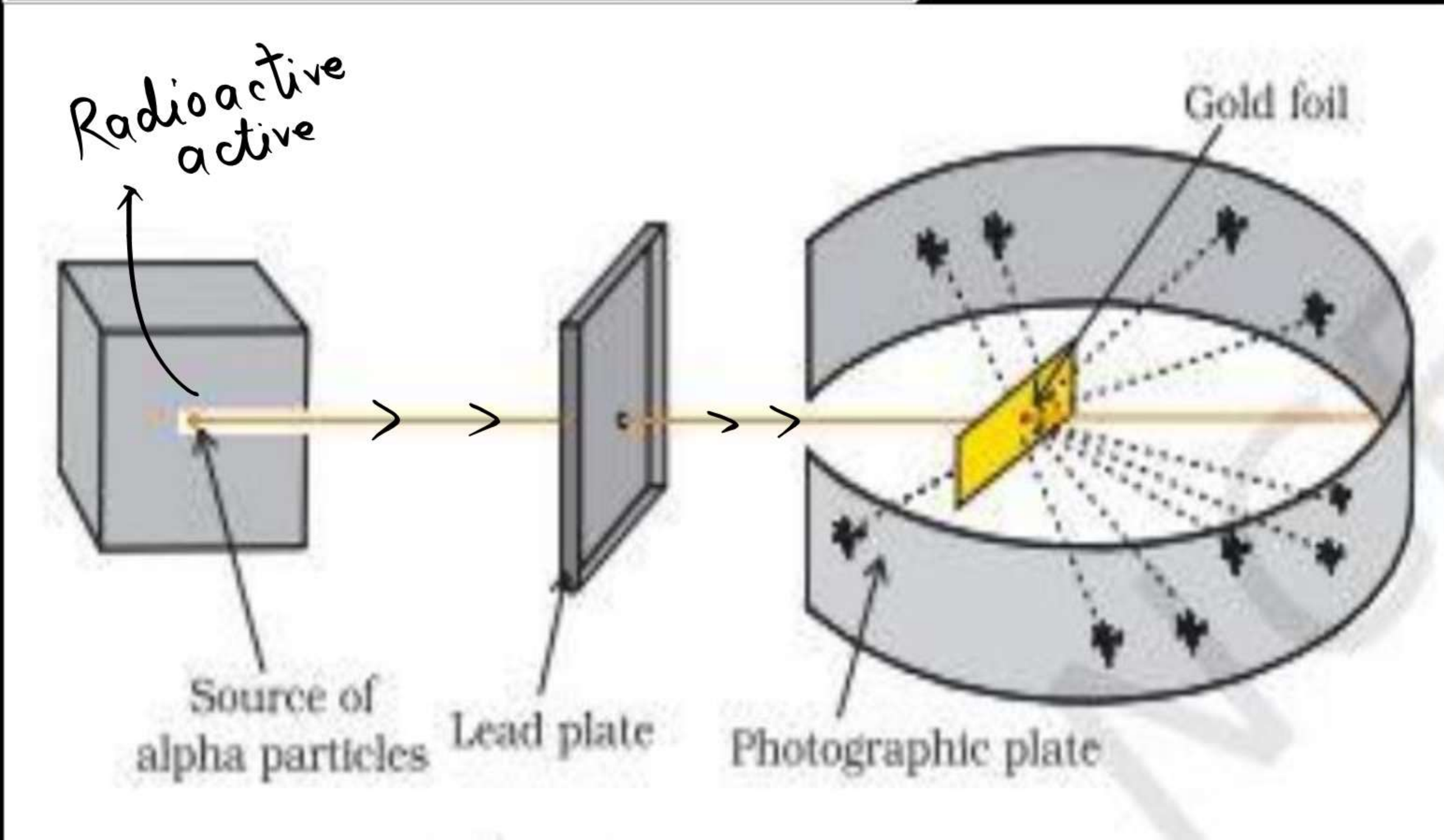
Atomic Models

Thomson's Model or Watermelon model
or
Plum pudding model or Raisin pudding model

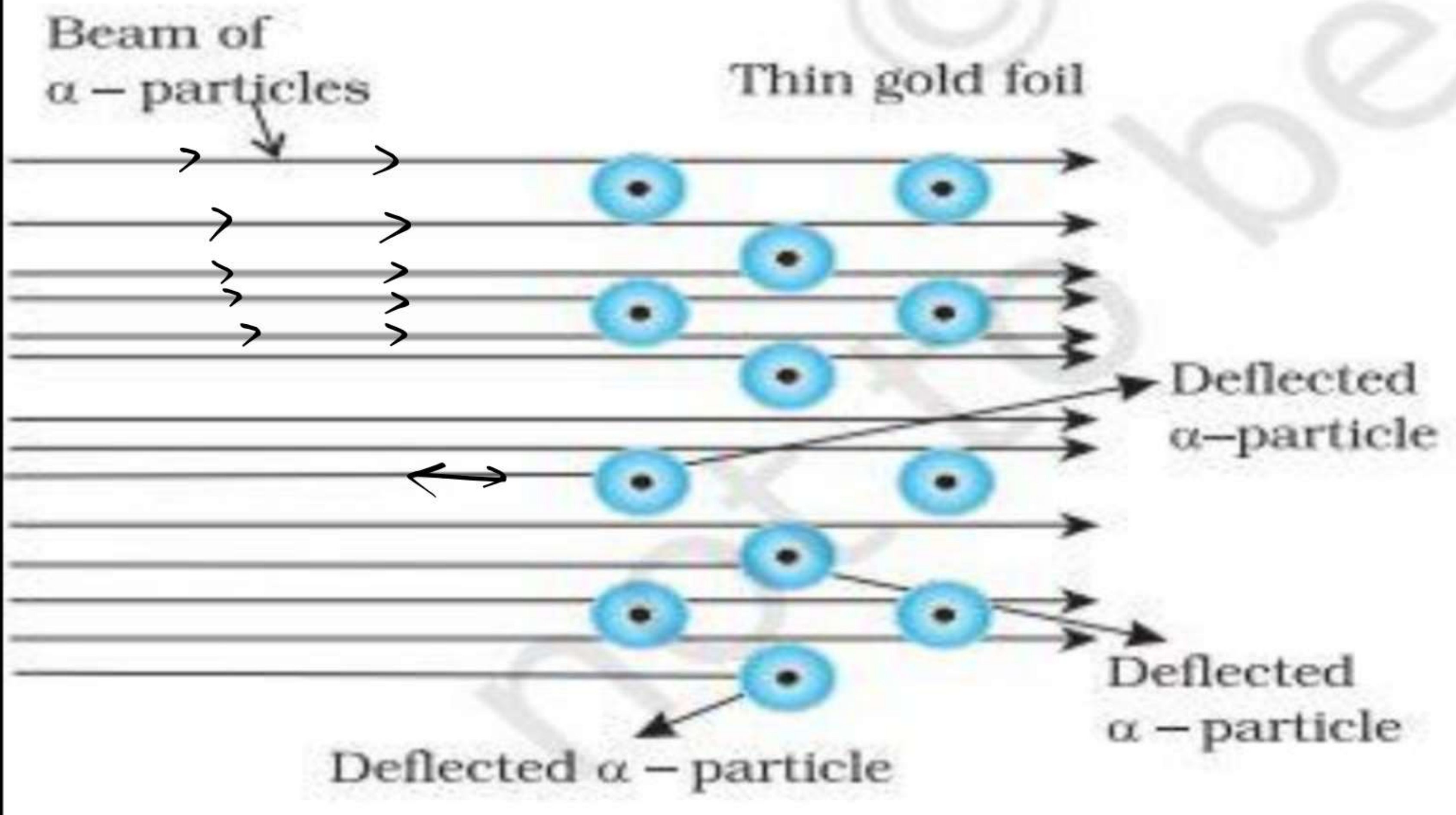
1. Atom consist of uniform +vely charged sphere in which e s are embedded
2. Atom is electrically neutral
   Total +ve charge = Total –ve charge



Rutherford α Particle Scattering Exp



Rutherford α Particle Scattering Exp



Rutherford α Particle Scattering Exp

1. Most of the alpha particle passed straight without any deflection
2. Some of them are deviated from their path
3. A few of them were bounced back

Rutherford Nuclear Concept

1. The atom of an element consist of a small +vely charged nucleus
2. The e^-s are revolved around nucleus in circular orbit
3. Total –Ve charge = Total +Ve charge
4. $V_{Nu} <<< V_{atom}$
5. most of the space is empty

$V_{Nu} = \frac{4}{3}\pi r_{Nu}^3$ $V_a = \frac{4}{3}\pi r_a^3$

$r_{Nu} \simeq 1\,\text{fm}$ $r_a = 1\,\text{Å}$

Q. The radius of an atomic nucleus is of the order of

1985, 1M

a. 10^{-10} cm

b. 10^{-8} cm

c. 10^{-15} m

d. 10^{-12} m

$1\ Fm = 10^{-15}\ m$

$1\ pm = 10^{-12}\ m$

$1\ \text{Å} = 10^{-10}\ m$

$1\ nm = 10^{-9}\ m$

Q*. The atomic nucleus contains

a. protons

b. neutrons

c. electrons

d. photons

1988, 1M

Q. The increasing order (lowest first) for the values of e/m (charge/mass) for electron (e), proton (p), neutron (n) and alpha particle (α) is

1984, 1M

$\frac{q}{m}$

a. e, p, n, α

b. n, p, e, α

c. n, p, α, e

d. n, α, p, e

$q_p = +1.6 \times 10^{-19}\,c$

$q_e = -1.6 \times 10^{-19}\,c$

$$\boxed{\begin{aligned} q_\alpha &= 2q_p \\ m_\alpha &= 4m_p \end{aligned}}$$

$m_p = 1840\, m_e$

$\frac{q_e}{m_e}$

$\frac{q_p}{m_p}$ p

$\frac{q_\alpha}{m_\alpha}$ α

$\frac{\cancel{2}q_p}{_2\cancel{4}m_p}$

Q. Rutherford's experiment, which established the nuclear model of the atom, used a beam of

(a) β–particles, which impinged on a metal foil and got absorbed (2002 3M)
(b) γ–rays, which impinged on metal foil and got scattered
(c) helium atoms, which impinged on a metal foil and got scattered
(d) helium nuclei, which impinged on a metal foil and got scattered

Q. Rutherford's scattering experiment is related to the size of the

1983, 1M

a. nucleus

b. atom

c. electron

d. neutron

Q. Rutherford's experiment on scattering of α–particles showed for the first time that atom has

1981, 1M

a. electrons

b. protons

c. nucleus

d. neutrons

Q. When alpha particles are sent through metal foil, most of them go straight through the foil, because

1984, 1M

(a) alpha particles are much heavier than electrons
(b) alpha particles are positively charged
(c) most part of the atom is empty space
(d) alpha particles move with high velocity

Q. Rutherford's alpha particle scattering experiment eventually led to the conclusion that

1986, 1M

(a) mass and energy are related
(b) electrons occupy space around the nucleus
(c) neutron are buried deep in the nucleus
(d) the point of impact with matter can be precisely determined

Relation b/w Radius of Nu & mass no.

$$R = R_0 (A)^{\frac{1}{3}} \text{ Fm}$$

R → Radius of Nu

R_0 → 1.2

A → mass no.

Q. Calculate radius of nucleus of atom having mass no.64

$$R = R_0 (64)^{1/3}$$
$$= 4R_0$$
$$= 4 \times 1.2$$
$$= 4.8 \text{ Fm}$$

Q. If the diameter of two diff nuclei are in the ratio 1 : 2 then their mass no. are in the ratio ?

(a) 1 : 2
(b) 8 : 1
(c) 1 : 8
(d) 1 : 4

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

$$\frac{d_1}{d_2} = \frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

$$\frac{1}{2} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

$$\frac{1}{8} = \frac{A_1}{A_2}$$

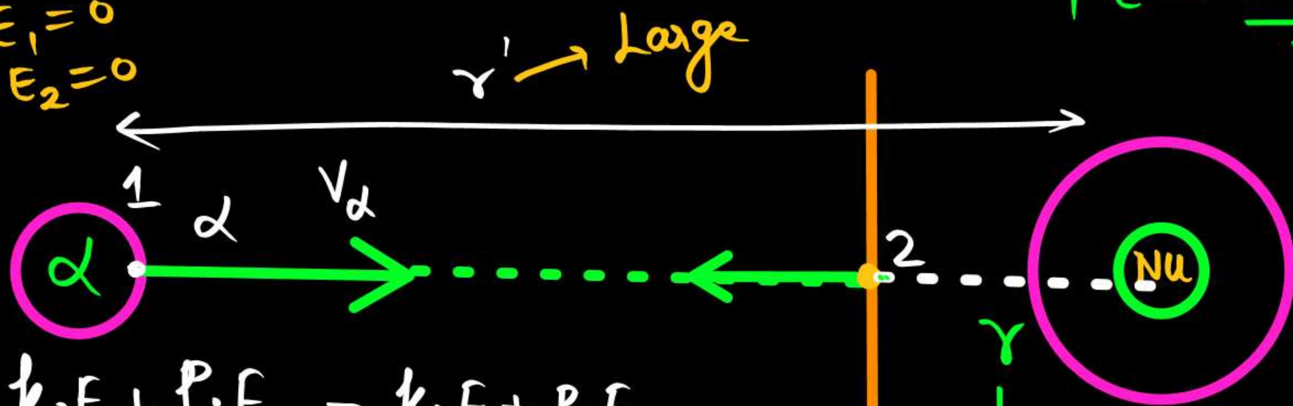
Distance of closest approach

$KE = \frac{1}{2} mv^2$

$$P.E = \frac{Kq_1q_2}{r} = \frac{K(2e)(Ze)}{r} = \frac{2KZe^2}{r}$$

$P.E_1 = 0$

$K.E_2 = 0$



r ↓ distance of closest approach

$$K.E_1 + P.E_1 = K.E_2 + P.E_2$$

$$\frac{1}{2} m_\alpha v_\alpha^2 + \cancel{\frac{2KZe^2}{r'}}^{\,0} = 0 + \frac{2KZe^2}{r}$$

for proton $\frac{1}{2} m_p v_p^2 = \frac{KZe^2}{r}$

$$\frac{1}{2} m_\alpha v_\alpha^2 = \frac{2kze^2}{r}$$

$$\boxed{r = \frac{4kze^2}{m_\alpha v_\alpha^2}}$$

$k = 9\times10^9$, z = at no. , $e = 1.6\times10^{-19}\,C$

(kg) m_α = mass of α-parti ($4m_p$)

($\frac{m}{s}$) v_α = velocity of α-parti m_p ✓

Q. With what velocity should and α–particle travel towards the nucleus of a copper atom so as to arrive at a distance 10^{-13}m from the nucleus of the copper atom? $z = 29$ $r = 10^{-13}$ m

(1997 (C), 3M)

$$r = \frac{4kze^2}{m_\alpha v_\alpha^2}$$

$$v_\alpha^2 = \frac{4\times 9\times 10^9 \times 29 \times (1.6\times 10^{-19})^2}{4\times 1.6\times 10^{-27}\times 10^{-13}} \quad m/s$$

Q. If α particle with speed V_0 is projected from infinity and it approaches up to r distance from nuclei then the speed of α-particle which approaches up to 2r distance from the nuclei will be.

(a) $\sqrt{2}V_0$

(b) $\frac{V_0}{\sqrt{2}}$

(c) $2V_0$

(d) $\frac{V_0}{2}$

$r \propto \frac{1}{V_\alpha^2}$

$\frac{r_2}{r_1} = \left(\frac{V_{\alpha_1}}{V_{\alpha_2}}\right)^2$

$\frac{2r}{r} = \left(\frac{V_0}{V_{\alpha_2}}\right)^2$

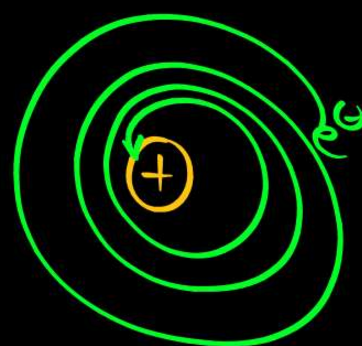
$\sqrt{2} = \frac{V_0}{V_{\alpha_2}}$

$\boxed{V_{\alpha_2} = \frac{V_0}{\sqrt{2}}}$

Drawback of Rutherford concept

Maxwell theory of electrodynamics

Acc^n to maxwell charge particles should emit radiations



Atomic no. & mass no.

$_{Z}X^{A}$

Z = Atomic no. = mass of proton (amu)

A = mass no. = mass of proton + mass of Neutron (amu)

Q. If mass of neutron is assumed to half of its original value whereas that of proton is assumed to be twice of its original value, then the atomic mass of $_6C^{14}$ will be

(a) Same (b) 14.28% more (c) 28.56% less (d) 42% more

A_1 = mass no. = 6 amu + 8 amu
= 14 amu

$A_2 = 2 \times 6 + \frac{1}{2} \times 8$ amu
$= 12 + 4$
$= 16$ amu

% change $= \frac{A_2 - A_1}{A_1} \times 100$

$= \frac{16-14}{14} \times 100$

$= 14.28\%$

Q. Calculate no. of e, p, & n

	e	P	n
(a) $^{27}_{13}Al^{3+}$	10	13	14
(b) $^{16}_{8}O^{2-}$	10	8	8
(c) $_{5}B^{11}$	5	5	6

Isoelectronic

Species having same number of electrons

Isotopes

Species having same atomic no but diff mass no.

Isobars

Species having same mass no but diff atomic no.

Isotones

Species having same number of neutrons

Isosters

Species having same number of electrons and atoms

2 atom N_2, CO 2 atom

$14 e^{\ominus}$ $14 e^{\ominus}$

Isodiaphers

Species having same number of n-p

$A-Z-Z$

$(A-2Z)$

$_{92}U^{238}$ $_{90}Th^{234}$

$(238-2\times 92)$ $(234-2\times 90)$

Q.* An isotone of ${}^{76}_{32}Ge$ is $76-32$ 44

a. ${}^{77}_{32}Ge$ 45

b. ${}^{77}_{33}As$

(1984, 1M)

c. ${}^{77}_{34}Se$ 43

d. ${}^{78}_{34}Se$

$$\begin{array}{r} 78 \\ 34 \\ \hline 44 \end{array}$$

Q*. Which of the following is/are isoelectronic ?

(a) CO_3^{2-}, NO_3^{-}

(b) SO_4^{2-}, PO_4^{3-}

(c) CO_2, N_2O

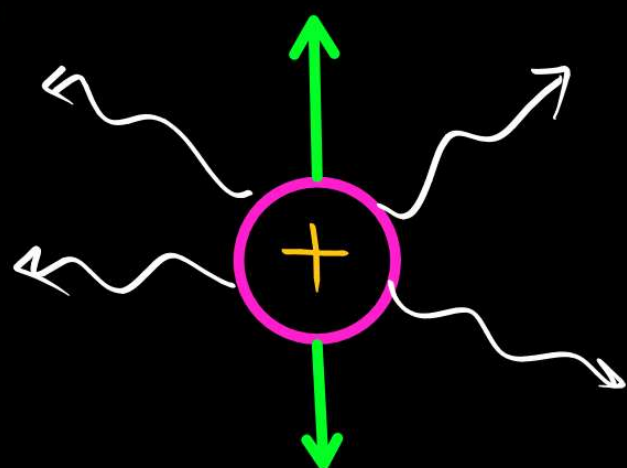
(d) N^{3-}, Al^{3+}

6+16 14+8

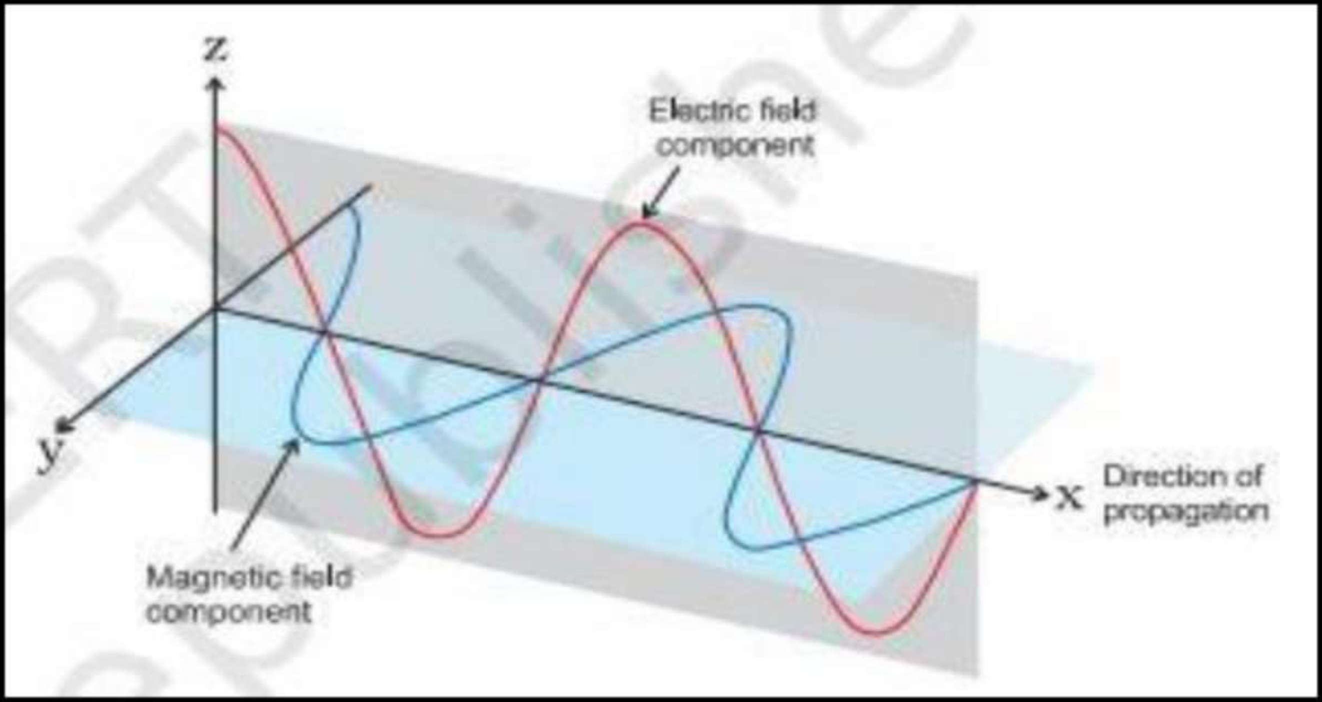
22 22

Electromagnetic radiation

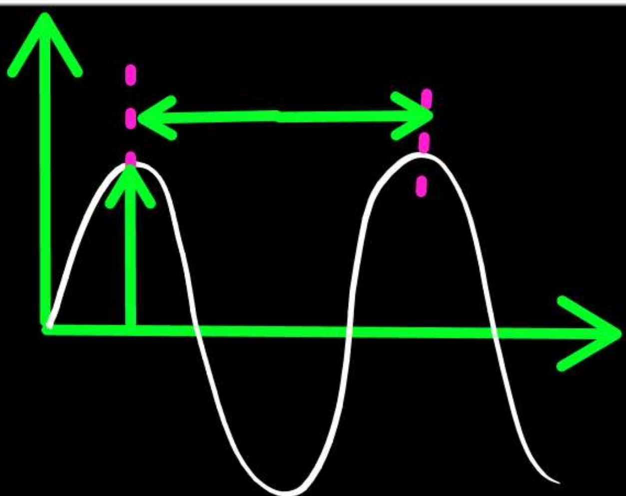
when electrically charged particle moves under acceleration , alternating electrical and magnetic fields are produced and transmitted. These fields are transmitted in the forms of waves called electromagnetic waves or electromagnetic radiation.



Electromagnetic radiation



Charac E.M radiations



1. wave length (λ)
2. Amplitude ✓
3. velocity ($c = 3 \times 10^8$ m/s)
4. frequency (ν) (Hz or s^{-1})
5. Wave no. ($\frac{1}{\lambda}$ or $\bar{\nu}$)

formula

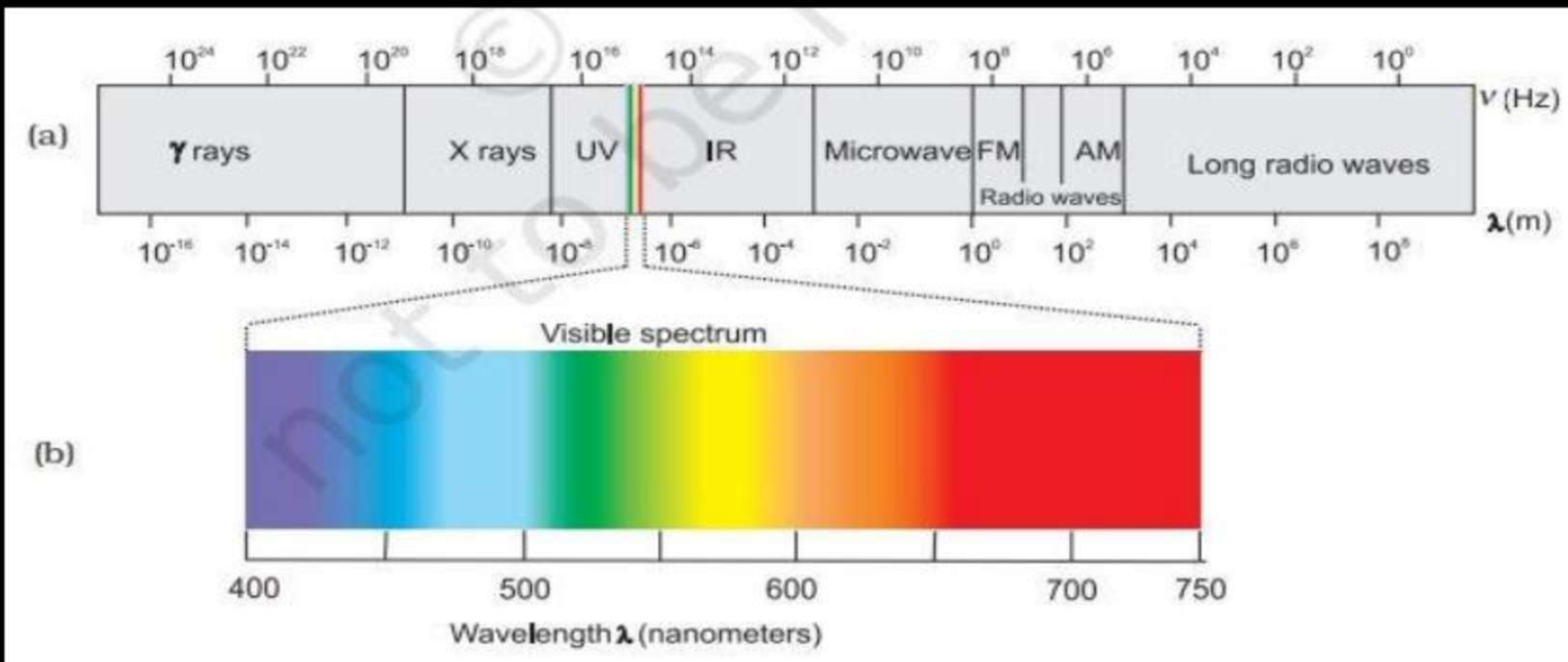
$$\boxed{C = \nu \lambda}$$

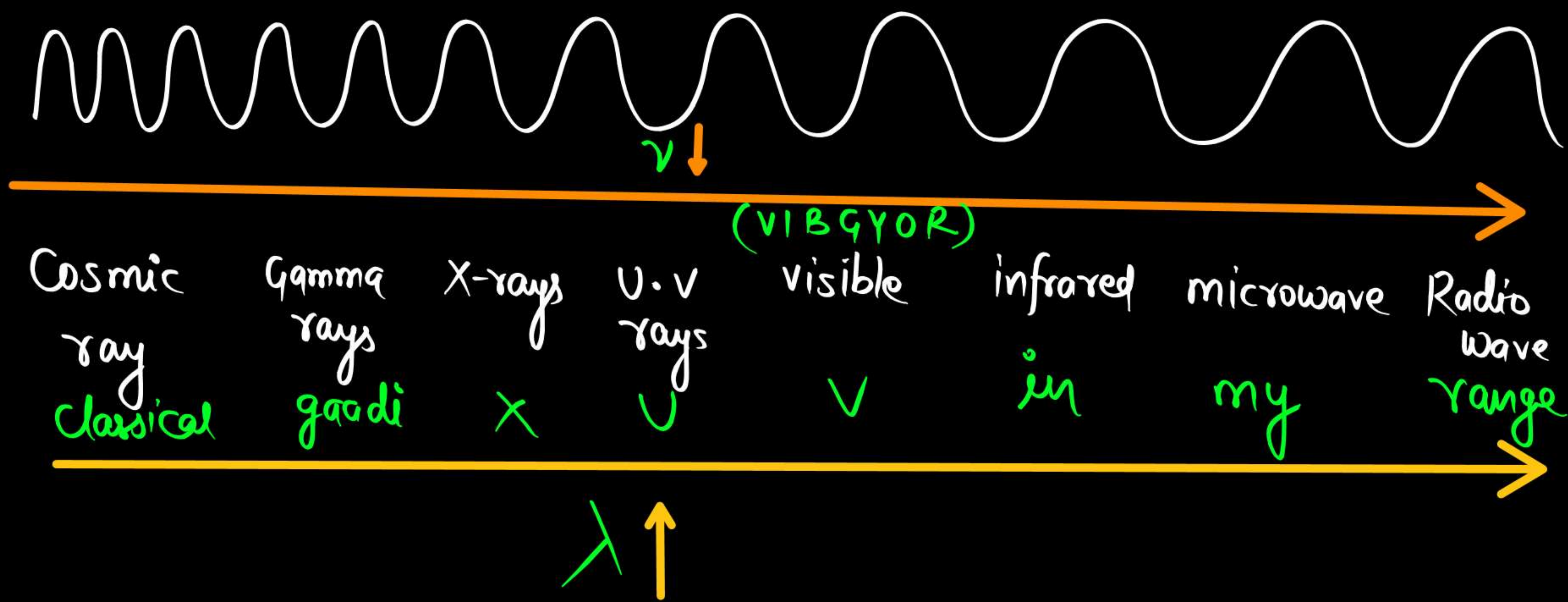
3×10^8

freq

Wave length

Electromagnetic Spectrum




ν
(VIBGYOR)
Cosmic ray
Gamma rays
X-rays
U.V rays
visible
infrared
microwave
Radio wave
classical
gaadi
X
U
V
in
my
range
λ

Q. Electromagnetic radiation with maximum wavelength is

a. ultraviolet

b. radio wave

c. X-ray

d. infrared

(1985, 1M)

Q. Which has highest frequency?

a. x rays

b. yellow

c. Infrared

d. Radio wave

Solution:

Black body Radiation

1. When solids are heated they emit radiation over a wide range of wavelengths.

For example, when an iron rod is heated in a furnace, it first turns to dull red and then progressively becomes more and more red as the temperature increases. As this is heated further, the radiation emitted becomes white and then becomes blue as the temperature becomes very high

2. The ideal body, which emits and absorbs radiations of all frequencies, is called a black body and the radiation emitted by such a body is called black body radiation

Black body Radiation

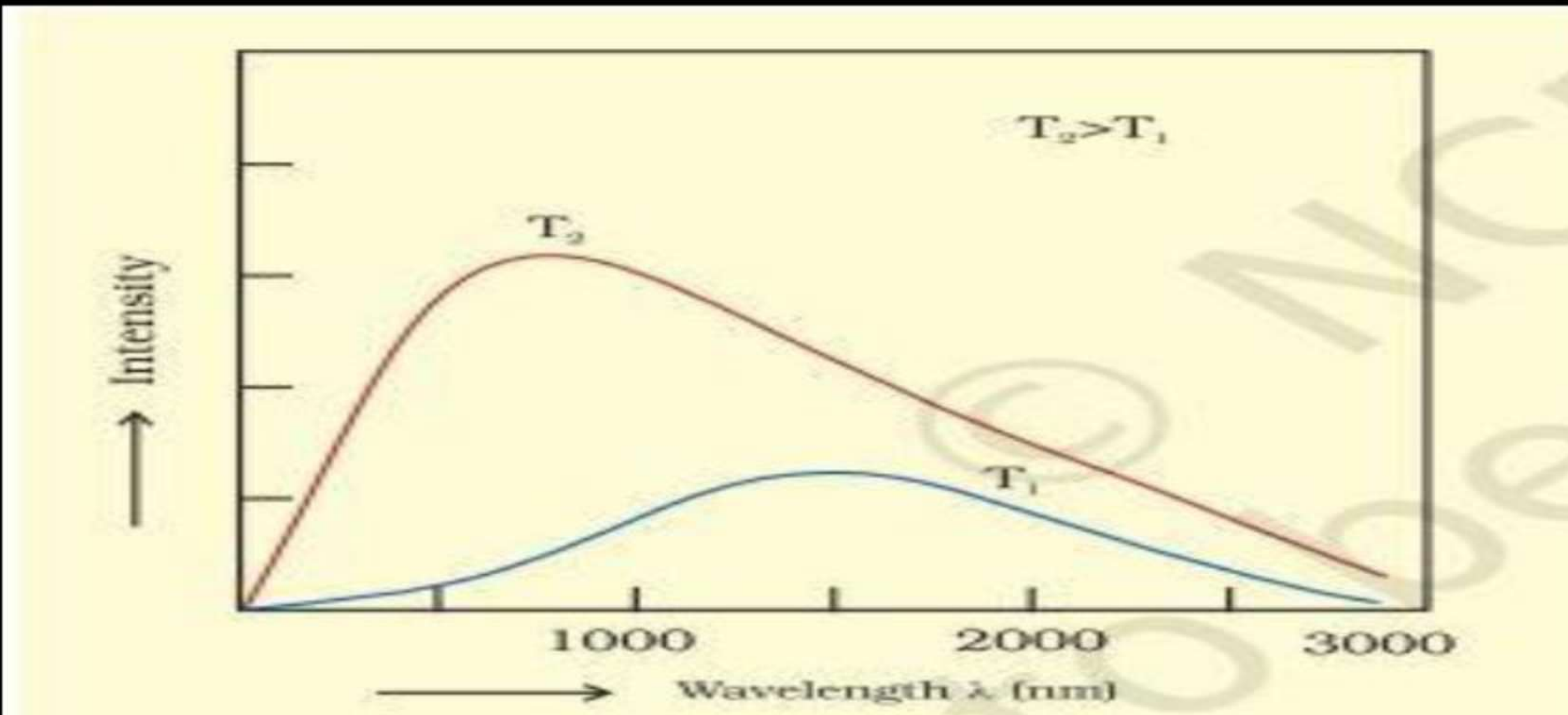
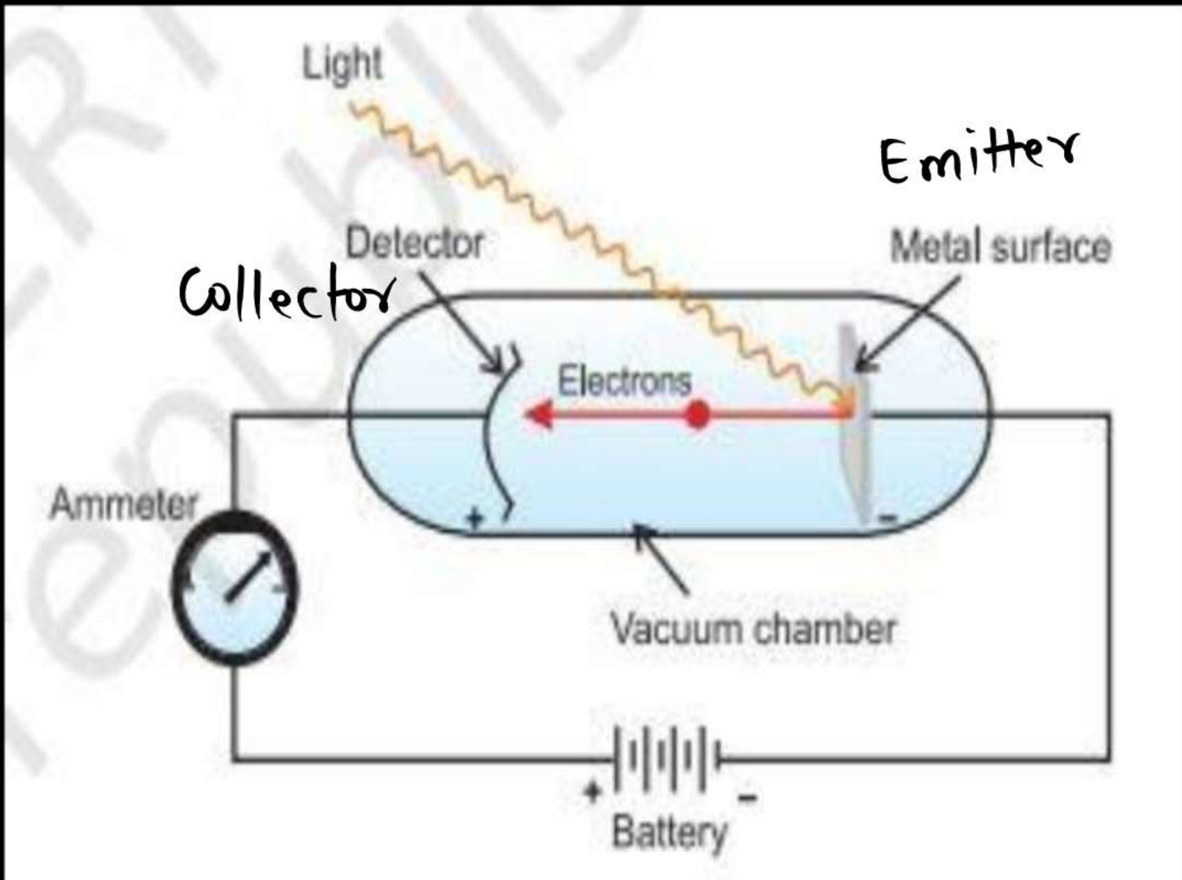


Photo-electric Effect



Henrich Hertz (1887)

frequency ↑, K.E of ejected $e^{\ominus}$ ↑

Intensity ↑, No. of ejected $e^{\ominus}$ ↑

Photo-electric Effect

1887 – 1905
1901
1921

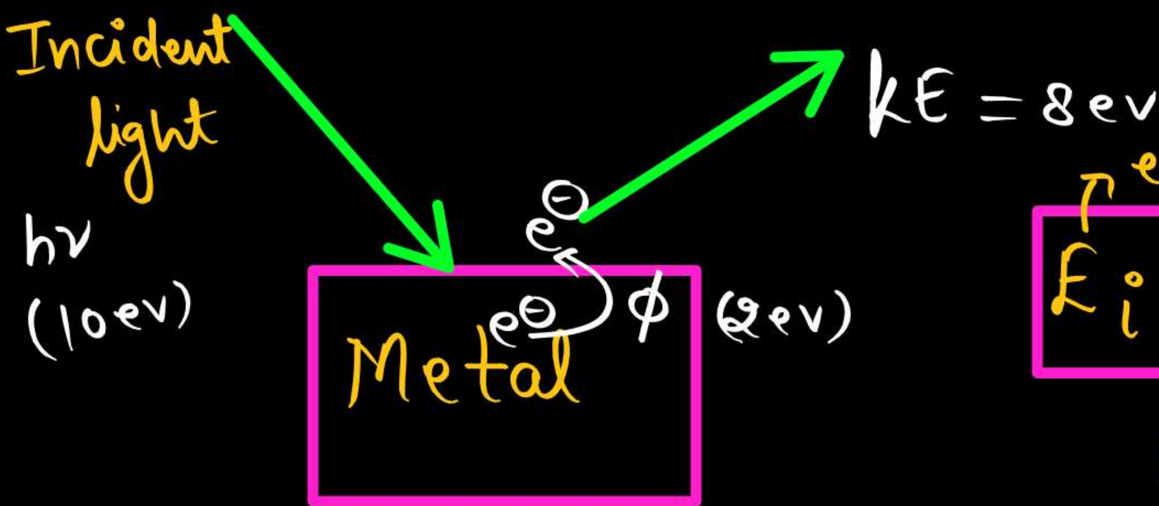
Photoelectric effect. The results observed in this experiment were:

(i) The electrons are ejected from the metal surface as soon as the beam of light strikes the surface, i.e., there is no time lag between the striking of light beam and the ejection of electrons from the metal surface.

(ii) The number of electrons ejected is proportional to the intensity or brightness of light.

(iii) For each metal, there is a characteristic minimum frequency, v0 (also known as threshold frequency) below which photoelectric effect is not observed. At a frequency $v > v_0$, the ejected electrons come out with certain kinetic energy.

(iv) The kinetic energies of these electrons increase with the increase of frequency of the light used.



energy of incident light

$$\boxed{E_i = \phi_{min} + K.E_{max}}$$

ϕ_{min} → (or W) min energy

$K.E_{max}$ → K.E

$$\boxed{h\nu = h\nu_0 + K.E}$$

$$\boxed{\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + K.E}$$

h = planck's const

ν = freq of incident light

ν_0 = Threshold freq (min)

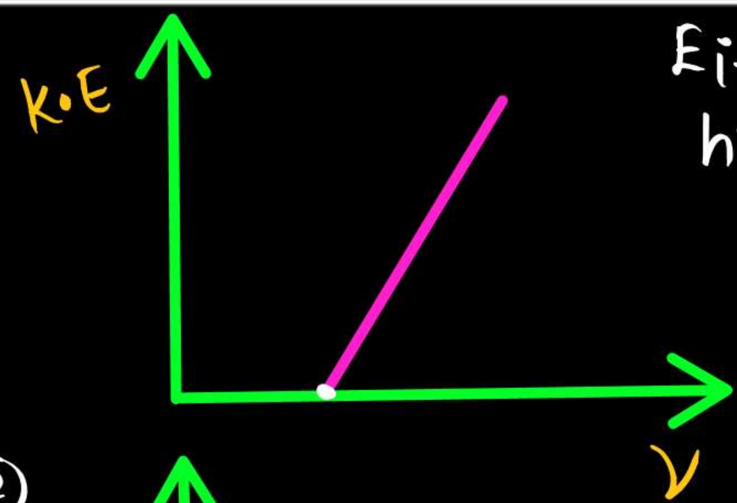
λ = wave length of incident light

λ_0 = Threshold wave length (max)

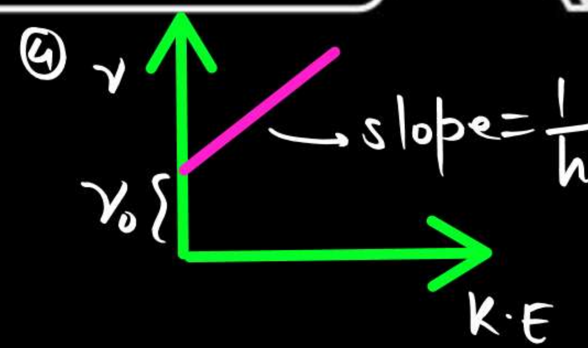
Graphs

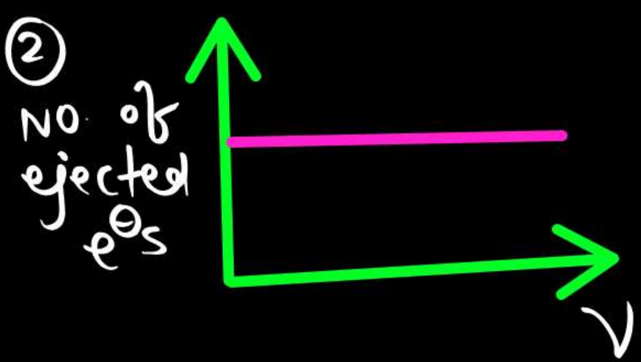
$$h\nu = h\nu_0 + KE$$
$$\nu = \frac{1}{h}KE + \nu_0$$

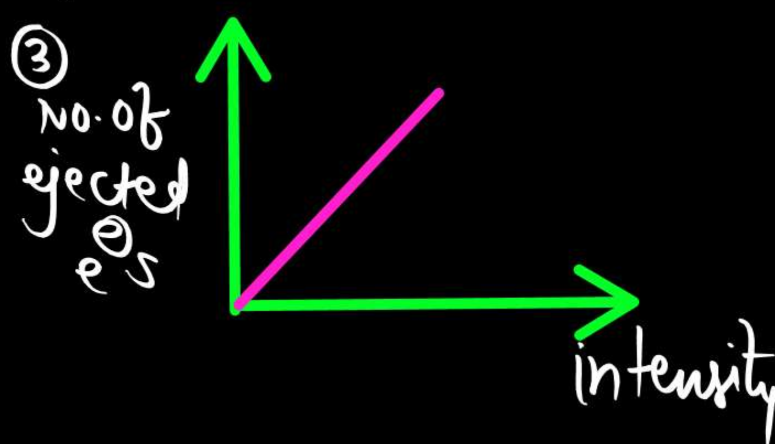
① K.E vs ν



$$E_i = \phi + KE$$
$$h\nu = h\nu_0 + KE$$
$$KE = h\nu - h\nu_0$$
$$y = mx - c$$







Stopping potential

The minimum potential which must be applied to stop P.E.E.

$$K.E = q \times V_0 \longrightarrow \text{stopping potential}$$

$$\boxed{K.E = eV_0}$$

Q. Calculate K.E (J) of an e^- emitted when radiation of freq $1.1 \times 10^{15}\ s^{-1}$ Hits the metal ($v_0 = 6 \times 10^{14}\ S^{-1}$)

11×10^{14}

Solution:

$$E_i = \phi + K.E$$

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

$$\boxed{E_i = \frac{12400}{\lambda(\text{Å})}\ eV}$$

$$1\ eV = 1.6 \times 10^{-19}\ J$$

$$h\nu = h\nu_0 + K.E$$

$$h(11 \times 10^{14}) = h(6 \times 10^{14}) + KE$$

$$KE = h(5 \times 10^{14})$$

$$K.E = 6.6 \times 10^{-34} \times 5 \times 10^{14}\ J$$

Q. Which of the graphs shown below does not represent the relationship between incident light and the electron ejected from metal surface?

E_i

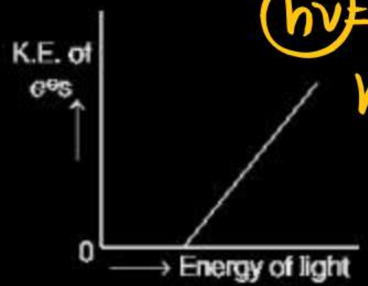
$h\nu = h\nu_0 + KE$

$KE = E_i - h\nu_0$

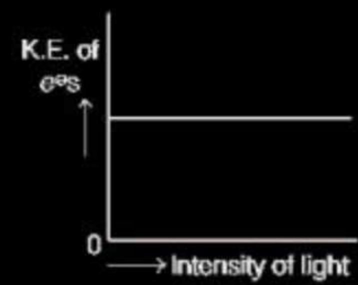
$y = mx - c$

(2019 Main, 10 Jan I)

(a)

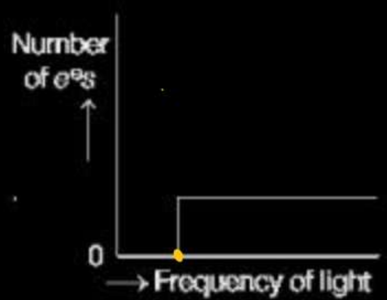


(b) ×



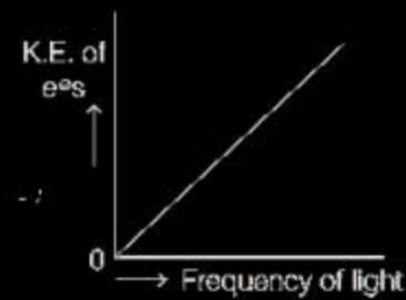
$I\uparrow$ no. of ejected $e^{\ominus}$s $\uparrow$

(c)



$\nu\uparrow$, $KE\uparrow$

(d)



$KE = h\nu - h\nu_0$

$y = mx - c$

$h\nu = h\nu_0 + KE$

Q. What is the work function of the metal, if the light of wavelength 4000 Å generates photoelectron of velocity 6×10^5 m/s from it?
(Mass of electron = 9×10^{-31} kg
Velocity of light = 3×10^8 ms^{-1}
Planck's constant = 6.626×10^{-34} J-s)

$$KE = \frac{\frac{1}{2} \times 9 \times 10^{-31} \times (6 \times 10^{5})^2}{1.6 \times 10^{-19}} eV$$

$$KE = 1.01$$

$$E_i = \frac{12400}{4000} eV$$

$$E_i = 3.1 eV$$

a. 4.0 eV

b. 2.1 eV

c. 0.9 eV

d. 3.1 eV

$\underbrace{\text{(2019 Main, 12 Jan I)}}_{\text{Taaza-Taaza}}$

$$E_i = \phi + K.E$$

$$3.1 eV = \phi + 1.01$$

$$\phi = 2.1 eV$$

Q. Light of $\lambda = 310\text{nm}$ is used in an exp of P.E.E with Li (w = 2.5 ev)

$310\text{nm} \rightarrow 3100\,\text{Å}$

Find (a) K.Emax (b) Stopping potential

Solution:

$$E_i = \phi + KE$$

$$\frac{\cancel{12400}^{\,4}}{\cancel{3100}} = 2.5 + KE$$

$$\boxed{KE = 1.5\ eV}$$

$$\boxed{V_0 = 1.5\ V}$$

Planck's Quantum theory

1. Planck suggested that atoms and molecules could emit (or absorb) energy only in discrete quantities and not in a continuous manner.
2. Planck gave the name quantum to the smallest quantity of energy that can be emitted or absorbed in the form of electromagnetic radiation

quantum

$E \propto \nu$

for 1 quantum $E = h\nu$

for n quantum $E = nh\nu$

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

$$\boxed{E(eV) = \frac{n\,12400}{\lambda(\text{Å})}}$$

ν = freq

λ = wave length

E = Energy

n = no. of quantums.

h = planck's Const
= 6.6×10^{-34} J-s

Q. No of photons emitted by a bulb of 40 watt in 1 min with 50% efficiency will be? (λ = 620 nm)

Solution: $\lambda = 6200\ \text{Å}$

$$E = \frac{n \times 12400}{\lambda(\text{Å})}\ eV$$

$$\frac{\overset{600}{\cancel{1200}}}{1.6 \times 10^{-19}} = \frac{n \times \overset{2}{\cancel{12400}}}{\cancel{6200}}$$

$$n = \frac{600}{1.6 \times 10^{-19}}$$

$$E = P \times t \times \frac{50}{100}$$

$$= 40 \times 60 \times \frac{1}{2}$$

$$= 1200\ J$$

$$E = \frac{1200}{1.6 \times 10^{-19}}\ eV$$

Bohr's Theory (for $1e^{\ominus}$ system
$H, He^{+}, Li^{2+} \ldots Na^{10+}$ etc

1. The electron in the hydrogen atom can move around the nucleus in a circular path of fixed radius and energy. These paths are called orbits, stationary states or allowed energy states. These orbits are arranged concentrically around the nucleus.
2. The energy of an electron in the orbit does not change with time , electron will move from a lower stationary state to a higher stationary state when required amount of energy is absorbed by the electron or energy is emitted when electron moves from higher stationary state to lower stationary state
3. The frequency of radiation absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by

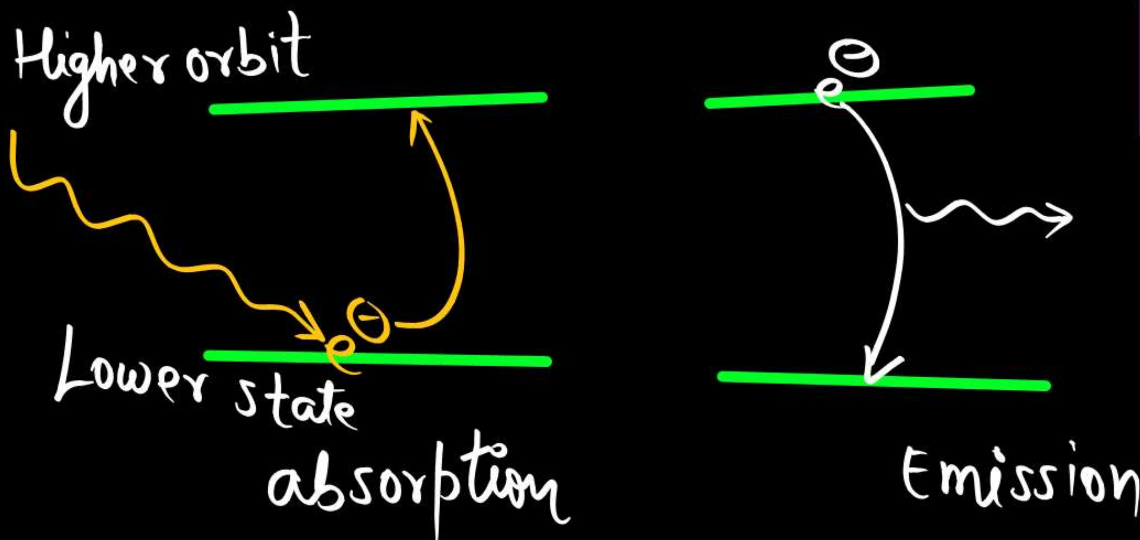
$$\Delta E = \frac{hc}{\lambda} \qquad \lambda = \frac{hc}{\Delta E} \qquad c = \nu \lambda$$

Bohr's Theory

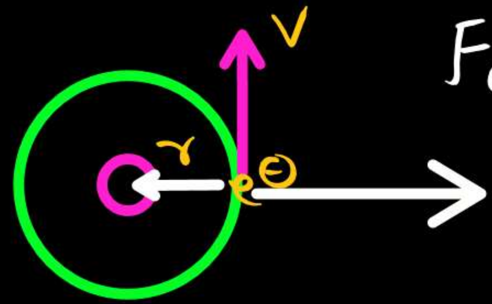
4. The angular momentum of an electron in a given stationary state can be expressed as

orbit angular momentum $mvr = \frac{nh}{2\pi}$ $\left[\hbar = \frac{h}{2\pi}\right]$

$\boxed{mvr = n\hbar}$ n = orbit



Bohr's



$$F_{attrc^n} = \frac{K q_1 q_2}{r^2} = \frac{K (ze)(e)}{r^2}$$

$$= \frac{Kze^2}{r^2} \quad -①$$

for stability

$$F_{centri} = \frac{mv^2}{r} \quad -②$$

$$F_{attrc^n} = F_{centri}$$

$$\frac{Kze^2}{\cancel{r^2}} = \frac{mv^2}{\cancel{r}}$$

$$\boxed{r = \frac{Kze^2}{mv^2}}$$

$$\left(mv^2 = \frac{Kze^2}{r} \right)$$

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

$$\cancel{m}\cancel{v} \times \frac{Kze^2}{\cancel{m}v^2} = \frac{nh}{2\pi}$$

$$\boxed{V = \frac{2\pi Kze^2}{nh}}$$

$$\boxed{V = 2.18 \times 10^6 \times \frac{Z}{n} \, m/s}$$

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

$$m \times \frac{2\pi Kze^2}{nh} \times r = \frac{nh}{2\pi}$$

$$\boxed{r = \frac{n^2h^2}{4\pi^2 mKze^2}}$$

$$\boxed{r = 0.53 \times \frac{n^2}{Z} \, \text{Å}}$$

$$r = (r_0 \text{ or } a_0) \times \frac{n^2}{Z} \, \text{Å}$$

r_0 or a_0 = Bohr Radius

Energy

$$T.E = K.E + P.E$$

$$T.E = \frac{kze^2}{2r} - \frac{kze^2}{r}$$

$$T.E = -\frac{kze^2}{2r}$$

$$\boxed{T.E = -K.E = \frac{P.E}{2}}$$

$$T.E = -\frac{kze^2}{\cancel{2} \times n^2h^2} \times \cancel{4}^{2}\pi^2 mkze^2$$

$$T.E = -\frac{2\pi^2 mk^2z^2e^4}{n^2h^2}$$

$$KE = \frac{1}{2}mv^2$$

$$= \frac{1}{2}\left(\frac{kze^2}{r}\right) = \frac{kze^2}{2r}$$

$$PE = -\frac{kq_1q_2}{r}$$

$$= -\frac{k(ze)e}{r}$$

$$= -\frac{kze^2}{r}$$

$$\boxed{T.E = -13.6 \times \frac{z^2}{n^2}\ eV}$$

Formulae

① $r = 0.53 \times \frac{n^2}{Z}$ Å

② $V = 2.18 \times 10^6 \times \frac{Z}{n}$ m/s

③ $TE = -13.6 \times \frac{Z^2}{n^2}$ eV

④ $mvr = \frac{nh}{2\pi}$

⑤ $TE = -KE = \frac{PE}{2}$

⑥ $\text{Timeperiod} = \frac{2\pi r}{V}$

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

⑦ $\text{freq} = \frac{1}{T}$

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

Q. Find orbit A.M of 5th orbit?

Solution:

$$O.A.M = \frac{nh}{2\pi}$$

$$= \frac{5h}{2\pi}$$

Q. Find orbit A.M   OAM $= n\hbar$

a. $\overset{n}{4}\,P$ $4\hbar$

b. $\overset{n}{5}d$ $5\hbar$

c. $\overset{n}{1}s$ $1\hbar$

d. $\overset{n}{6}f$ $6\hbar$

Solution:

Definitions valid for 1 e system

① Ground state (G.S) $n=1$

② Excited state (E.S) $n = 2, 3, 4, 5, 6 \ldots$

1st E.S (n = 2), 2nd E.S (n = 3), 3rd E.S (n = 4)

③ Ionisation energy (I.E) $n=1 \longrightarrow n=\infty$

$$T.E = -13.6 \times \frac{z^2}{n^2}$$

$$I.E = E_\infty - E_1$$

$$I.E = 0 - \left(-13.6 \times \frac{z^2}{1^2}\right)$$

$$\boxed{I.E = +13.6 \times z^2}$$

④ Excitation energy :-
(E.E)

$$n=1 \longrightarrow \underbrace{(n-1)^{th}}\ \text{Excited state}$$

$$E.E = E_n - E_1$$

$$= -13.6 \times \frac{z^2}{n^2} - \left(-13.6 \times \frac{z^2}{1^2}\right)$$

$$\boxed{E.E = 13.6 \times z^2 \left[1 - \frac{1}{n^2}\right]}$$

(5) Binding energy (B·E)

$$n \longrightarrow \infty$$

$$B \cdot E = E_{\infty} - E_n$$

$$= 0 - \left(-13.6 \times \frac{z^2}{n^2}\right)$$

$$\boxed{B \cdot E = +13.6 \times \frac{z^2}{n^2}}$$

$$\boxed{B \cdot E = \frac{I \cdot E}{n^2}}$$

Q. Find I.E of Li^{2+} ion? $z = 3$

Solution:

$$IE = +13.6 \times z^2$$
$$= 13.6 \times 3^2$$

Q. Find r, v, T.E, KE, PE of He^{+} in $\underbrace{1^{st} \text{ excited state}}_{n=2}$?

Solution:

$z=2$

① $r = r_0 \times \frac{2^2}{2}$ Å

② $v = 2.18 \times 10^6 \times \frac{2}{2}$ m/s

③ $T.E = -13.6 \times \frac{z^2}{2^2}$ ev

④ $KE = -T.E$

⑤ $TE = \frac{PE}{2}$

$PE = 2TE$

Q*. The energy of an electron in the first Bohr orbit of H-atom is $-13.6\ eV$. The possible energy value(s) of the excited state(s) for electrons in Bohr orbits of hydrogen is (are)

1988

a. -3.4 eV ✓

b. -4.2 eV ✗

c. -6.8 eV ✗

d. $+6.8$ eV ✗

$n = 2 \qquad n = 3 \quad ----$

$$TE = -13.6 \times \frac{1^2}{2^2}$$

$$= -3.4\ eV$$

Q. The ground energy of hydrogen atom is –13.6eV. The energy of second excited state of He^+ ion in eV is

$n=3$ $z=2$

(2019 Main, 10 Jan II)

Taaza-Taaza

a. –54.4

b. –3.4

c. –6.04

d. –27.2

Solution:

$$T.E = -13.6 \times \frac{z^2}{n^2}$$

$$= -13.6 \times \frac{2^2}{3^2}$$

Q. Which of the following is the energy of a possible excited state of hydrogen?

(2015 Main)

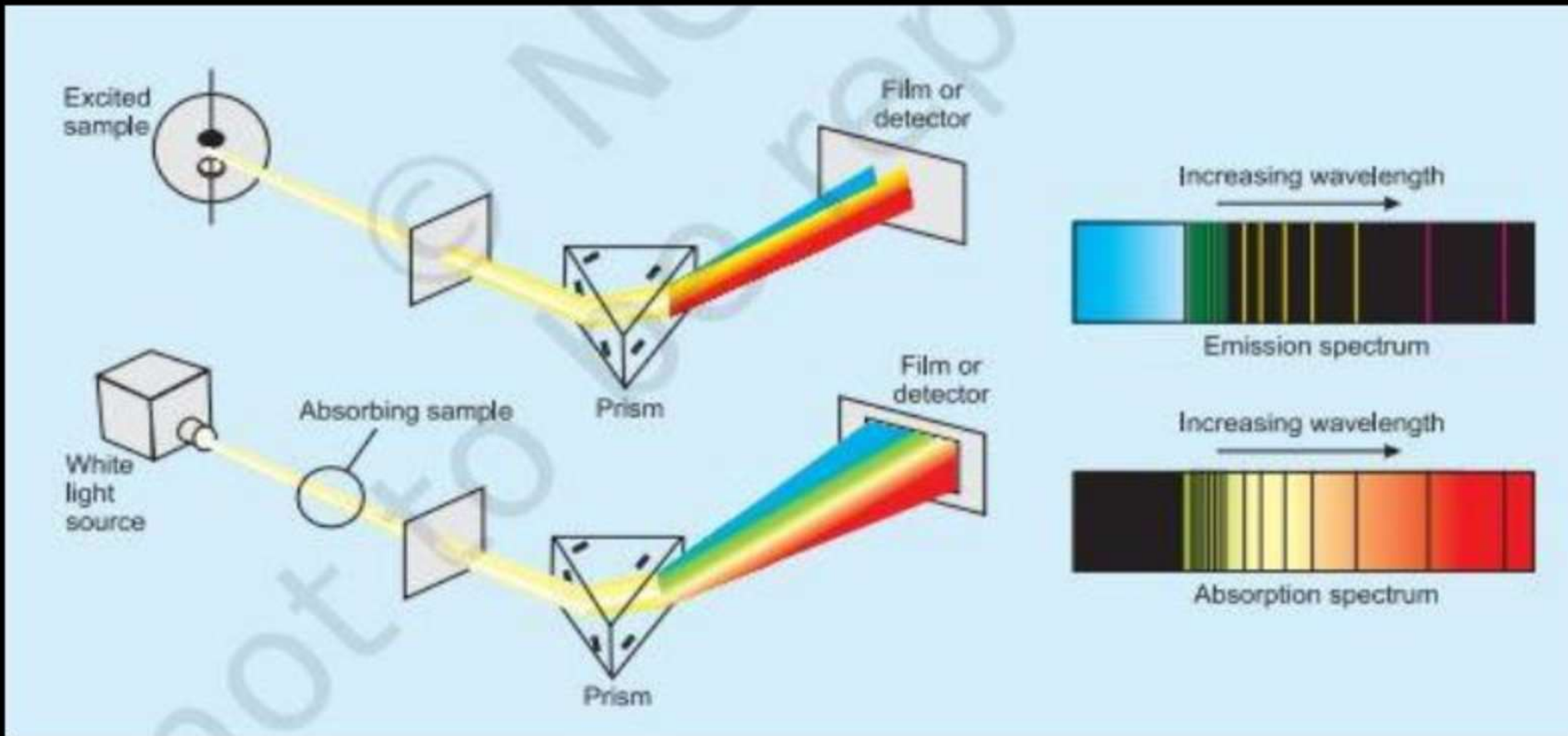
(a) + 13.6 eV
(b) −6.8 eV
(c) −3.4 eV
(d) + 6.8 eV

for 'H' atom

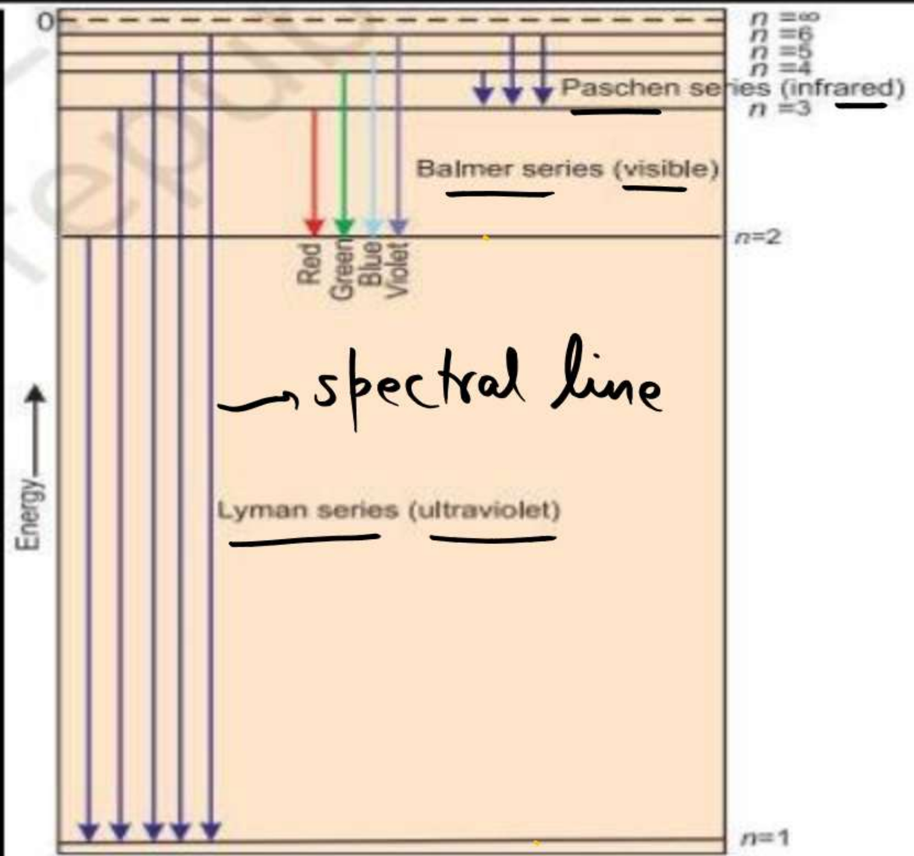
$n = 1 \quad TE = -13.6$

$n = 2 \quad T.E = -3.4$

Hydrogen Spectrum



Hydrogen Spectrum



Rydberg's formula

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

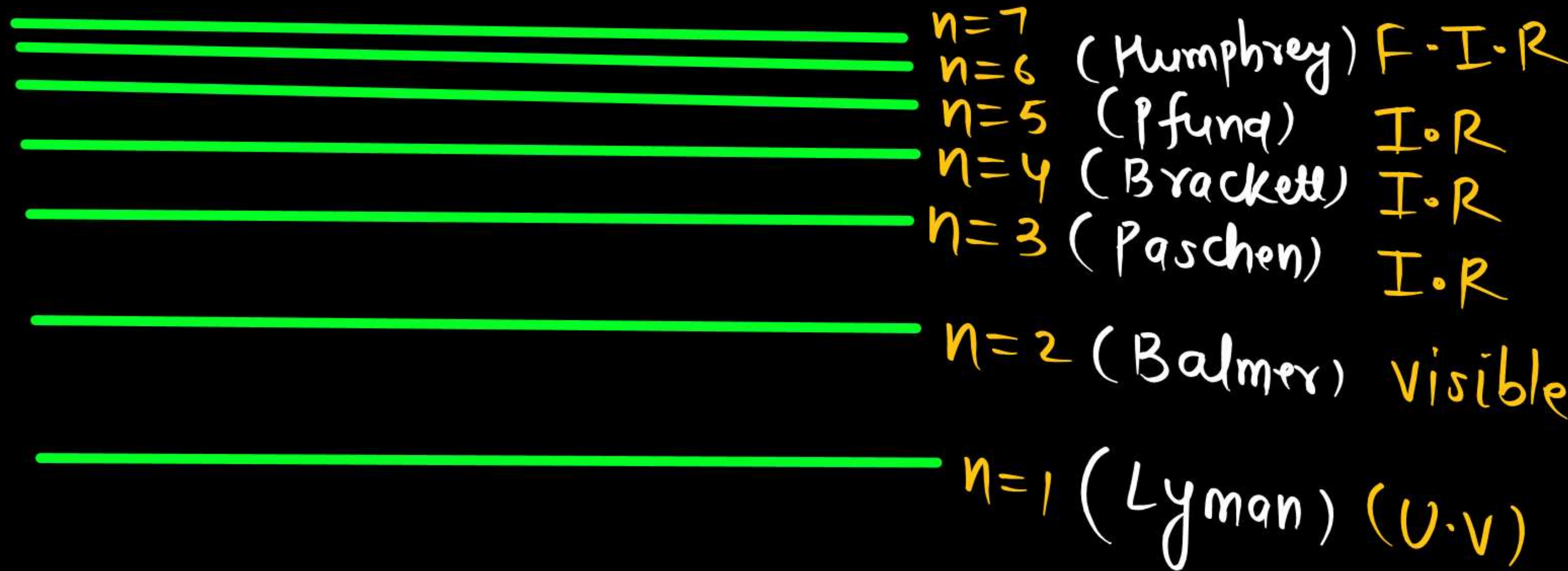
$$\boxed{\bar{\nu} = R_H Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$$

R_H = Rydberg's const = 109678 cm^{-1} = 1.1×10^5 cm^{-1}

n_1 = Lower energy level

n_2 = Higher " "

for H and H-like (He^{+}, Li^{2+}, Be^{3+} ..... Na^{10+} ... etc



Q. Bohr's model can explain

1985, 1M

(a) the spectrum of hydrogen atom only
(b) spectrum of an atom or ion containing one electron only
(c) the spectrum of hydrogen molecule
(d) the solar spectrum

Q. Calculate λ of radiation emitted when e^- makes transition from n = 2 to n = 1 in H atom?

Solution:

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

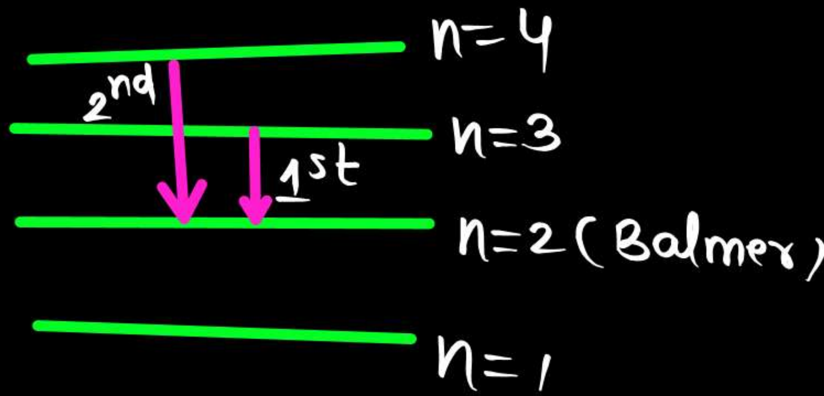
$$\frac{1}{\lambda} = R_H (1)^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

$$\frac{1}{\lambda} = R_H \left[1 - \frac{1}{4}\right]$$

$$\boxed{\lambda = \frac{4}{3R_H}}$$

Q. Calculate λ for 2^{nd} line of balmer series for He^{+} ion?

Solution:



$n_1 = 2$, $n_2 = 4$, $z = 2$

$$\frac{1}{\lambda} = R_H (2)^2 \left[\frac{1}{2^2} - \frac{1}{4^2}\right]$$

$$\boxed{\lambda = \frac{4}{3R_H}}$$

Q. Find series limit of Lyman series for Li^{2+}

Solution: Last line

$n_2 = \infty$, $n_1 = 1$, $z = 3$

$$\frac{1}{\lambda} = R_H (3)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$$

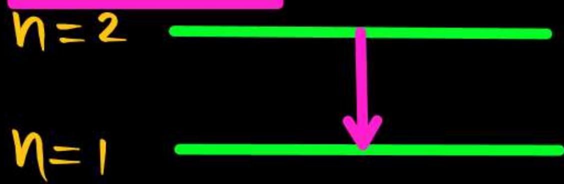
$$\boxed{\lambda = \frac{1}{9R_H}}$$

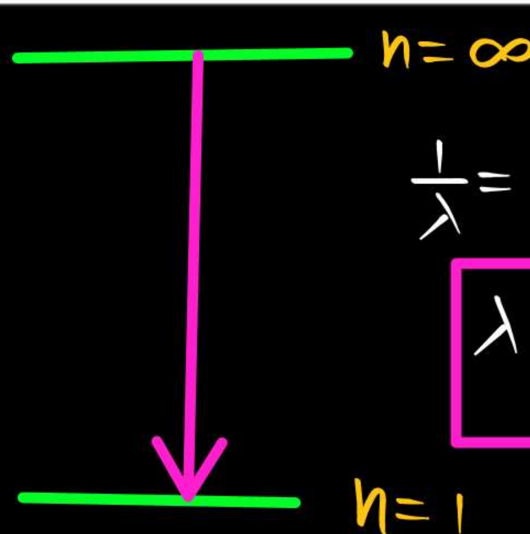
Q. Find λmax and λmin for Lyman series for H atom?

Solution:

$$\frac{1}{\lambda} = R_H (1)^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

$$\boxed{\lambda = \frac{4}{3R_H}}$$





$$\frac{1}{\lambda} = R_H (1)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$$

$$\boxed{\lambda = \frac{1}{R_H}}$$

Kisi Bhi series Ki 1^{st} line, apko λ_{max} deti Hai

" " " " Last " " λ_{min} " "

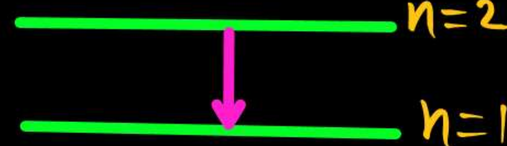
Q. Find λ for H_α line for Lyman series for He^+ ion ? $z=2$

Solution: $\alpha \rightarrow 1^{st}$ line

$\beta \longrightarrow 2^{nd}$ line

$\gamma \longrightarrow 3^{rd}$ line

⋮



$$\frac{1}{\lambda}=R_H(2)^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$$

$$\frac{1}{\lambda}=4R_H\left[1-\frac{1}{4}\right]$$

$$\boxed{\lambda=\frac{1}{3R_H}}$$

Q. Find $\bar{\nu}$ (wave no) when e^- makes transition from $\underbrace{3^{rd}\ E.S}_{n_2=4}$ to $\underbrace{\text{ground state}}_{n_1=1}$ in Be^{3+} ion?

$z=4$ $\quad \bar{\nu}=\frac{1}{\lambda}$

Solution:

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

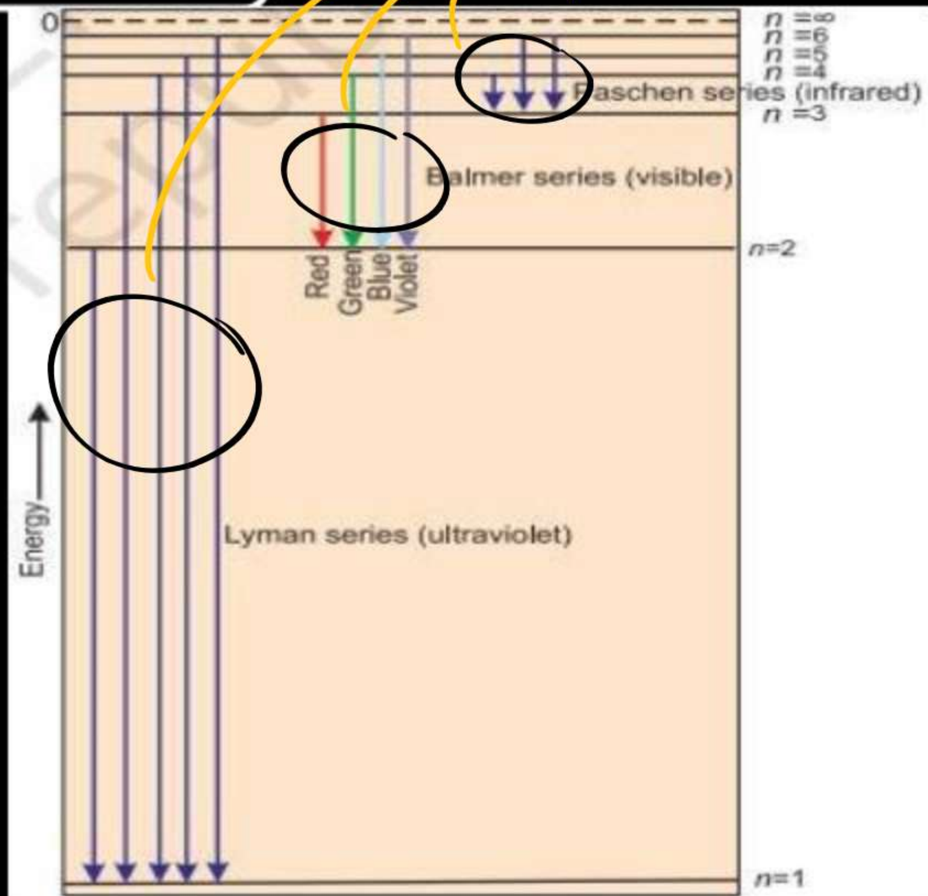
$$= R_H(4)^2\left[\frac{1}{1^2}-\frac{1}{4^2}\right]$$

$$= 16R_H\left[1-\frac{1}{16}\right]$$

$$= 15R_H$$

Spectral Lines

Spectral lines



n_1 = Lower level

n_2 = Higher level

① Total no. of spectral lines

$$= \frac{\Delta n(\Delta n+1)}{2}$$

$$\Delta n = n_2 - n_1$$

② Total no. of spectral lines in perticular series

$$= n_2 - n'$$

n_2 = Higher level

n' = Series no.

Q find Total no. of spectral lines when $e^{\ominus}$ makes transition from $n=4$ to $n=1$

$$\Delta n = 4-1 = 3$$

$$\text{Spectral lines} = \frac{3(3+1)}{2}$$

$$= \frac{3\times4}{2}$$

$$= 6$$

Q find total spectral lines in Balmer series when $e^{\ominus}$ makes transition from $n=10$ to ground state?

$n' = 2$

$$10 - 2 = 8$$

Zeemann Effect

The splitting of spectral lines in M.F

Stark Effect

The splitting of spectral lines in E.F

Q. Find total no. of spectral lines when e^- makes transition from 9^{th} E.S to 1^{st} E.S $n_1 = 2$ $n_2 = 10$

Solution: $\Delta n = 8$

$$\frac{8 \times (8+1)}{2}$$

$$4 \times 9$$

$$36$$

Q. Find spectral lines in balmer series when e^- makes transition from 14^{th} E.S to G.S?

$n' = 2$

$n_2 = 15$

Solution:

$n_2 - n'$

$15 - 2 = 13$

De-broglie hypothesis

The wave length associated with a particle of mass m moving with velocity v

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

h = planck's const
m = mass (kg)
v = velocity (m/s)

Debroglie hypothesis formulae

(a) $\lambda = \frac{h}{p}$

$p = mv$

(b) $\lambda = \frac{h}{mv}$

$KE = \frac{1}{2} mv^2$

$m\,KE = \frac{1}{2} m^2 v^2$

(c) $\lambda = \frac{h}{\sqrt{2mKE}}$

(d) $\lambda = \frac{h}{\sqrt{2mqv}}$

$m\,KE = \frac{p^2}{2}$

(e) fore$^{\ominus}$ $\lambda = \frac{12.24}{\sqrt{v}}$ Å

$\lambda = \sqrt{\frac{150}{V}}$ Å

(f) $2\pi r = n\lambda$ $\underbrace{\text{n = no. of wave no.}}$

$p = \sqrt{2mKE}$

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

$2\pi r = n \frac{h}{mv}$

$2\pi r = n\lambda$

$KE = q \times V$

$\downarrow$

potential diff

Q. Find λ when an e^- is moving with velocity of 10^6 m/s.

Solution:

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

$$\lambda = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 10^{6}} \text{ m}$$

Q. If the de-Broglie wavelength of the electron in n^{th} Bohr orbit in a hydrogenic atom is equal to $1.5\,\pi a_0$ (a_0 is Bohr radius), then the value of n/Z is

(a) 1.0
(b) 0.75
(c) 0.40
(d) 1.50

(2019 Main 12 Jan II)

$\underbrace{\hspace{4cm}}$

Taaza-Taaza

$$2\pi r = n\lambda$$

$$2\cancel{\pi} \times \cancel{a_0} \times \frac{n^{\cancel{2}}}{z} = \cancel{n} \times 1.5\,\cancel{\pi}\,\cancel{a_0}$$

$$\frac{n}{z} = \frac{1.5}{2}$$

Q. Find ratio of λ of α and proton $\left(\frac{\lambda\alpha}{\lambda p}\right)$ acc through same potential diff.

Solution:

$$\lambda = \frac{h}{\sqrt{2mqV}}$$

$$\lambda \propto \frac{1}{\sqrt{mq}}$$

$$\frac{\lambda_\alpha}{\lambda_p} = \sqrt{\frac{m_p q_p}{m_\alpha q_\alpha}}$$

$$= \sqrt{\frac{m_p q_p}{4m_p \times 2q_p}}$$

$$= \frac{1}{\sqrt{8}}$$

Q. The wavelength associated with a golf ball weighing 200 g and moving at a speed of 5 m/h is of the order

$m = 0.2\ kg$

a. 10^{-10} m

$v = \frac{5}{60 \times 60}$

b. 10^{-20} m

(2001, 1M)

c. 10^{-30} m

d. 10^{-40} m

Solution:

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

$$= \frac{6.6 \times 10^{-34} \times 60 \times 60}{0.2 \times 5}$$

Q. Find λ when an e^- is acc by a potential diff of 15 v from rest?

Solution:

$$\lambda = \sqrt{\frac{150}{V}}\ \text{Å}$$

$$\lambda = \sqrt{\frac{150}{15}}\ \text{Å}$$

$$\lambda = \sqrt{10}\ \text{Å}$$

Heisenberg's Uncertainly principle

we can not determine the exact position and momentum of a fast moving object at the same time.

$\Delta x \longrightarrow$ change in position, $\Delta p =$ change in momentum

$$\boxed{\Delta x \cdot \Delta p \geq \frac{h}{4\pi}}$$

$\Delta p = m\Delta v$

$\Delta x \times (m\Delta v) \geq \frac{h}{4\pi}$

$$\boxed{\Delta x \times \Delta v \geq \frac{h}{4\pi m}}$$

Δv = uncertainity in velocity

$\Delta t \times \Delta x \cdot \frac{\Delta p}{\Delta t} \geq \frac{h}{4\pi}$

$F\Delta x \times \Delta t \geq \frac{h}{4\pi}$

$$\boxed{\Delta E \times \Delta t \geq \frac{h}{4\pi}}$$

Uncertainty in Energy ΔE

" " time Δt

Q. If $\Delta x = 2\Delta P$ then find Δv ?

Solution:

$$\Delta x = 2(m\Delta v)$$

$$\Delta x = 2m\Delta v$$

$$\Delta x \, \Delta v = \frac{h}{4\pi m}$$

$$2m\Delta v^2 = \frac{h}{4\pi m}$$

$$\Delta v^2 = \frac{h}{8\pi m^2}$$

$$\Delta v = \sqrt{\frac{h}{8\pi m^2}}$$

Q. If Δ x is 10^{-5} m of a particle of mass 0.25 gm then find Δ v ?

$m = 0.25 \times 10^{-3}$

Solution:

$$\Delta x \times \Delta v = \frac{h}{4\pi m} = \frac{0.53 \times 10^{-34}}{m}$$

$$\boxed{\frac{h}{4\pi} = 0.53 \times 10^{-34}}$$

$$10^{-5} \times \Delta v = \frac{h}{4\pi (0.25 \times 10^{-3})}$$

$$\Delta v =$$

$m = 0.1\ kg$

Q. A golf ball has mass 100 gm and speed of 100m/s if the speed can be measured within accuracy of 2% find Δx?

Solution:

$$\Delta x\,\Delta v = \frac{0.53 \times 10^{-34}}{m}$$

$$\Delta x \times 2 = \frac{0.53 \times 10^{-34}}{0.1}$$

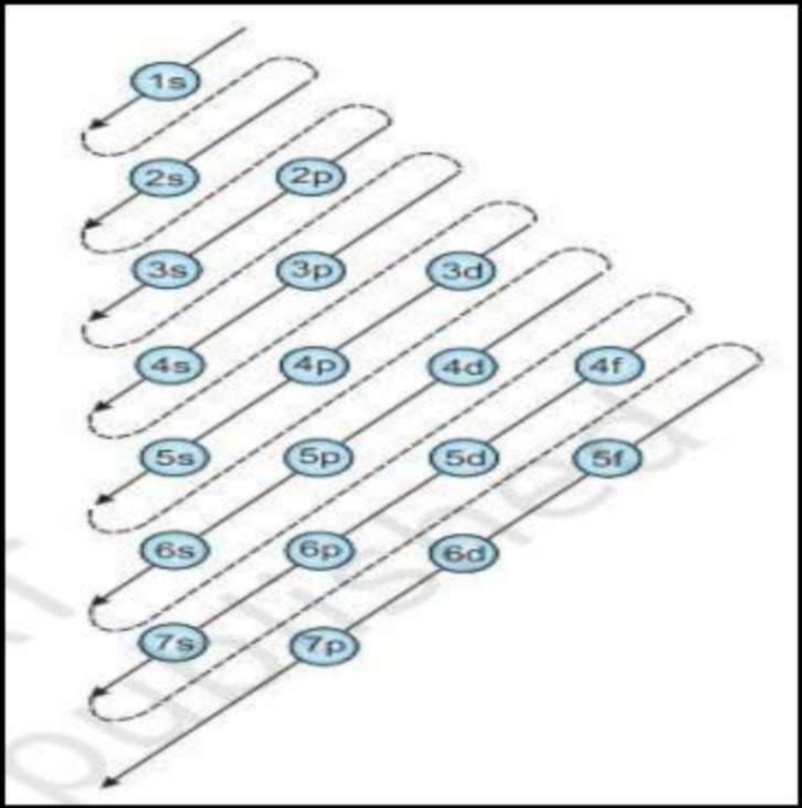
Uncertainity = Exact value × accuracy

$$\Delta v = \frac{100 \times 2}{100}$$

$$\Delta v = 2$$

Electronic Configuration

Aufbau's Rule



filling

Lower energy → Higher energy

1s < 2s < 2p < 3s < 3p < 4s < 3d

Hund's rule :- In degenerated orbitals ⟶ orbitals of equal energy.

p^3 | ↑ | ↑ | ↑ |

p^4 | ↑↓ | ↑ | ↑ |

Pauli's Rule :- No two $e^{\ominus}$s can have all the four quantum no. same.

Q. The ground state electronic configuration of nitrogen atom can be represented by

$_7N \; 1s^2 2s^2 2p^3$

a. $\boxed{\uparrow\downarrow}\ \boxed{\uparrow\downarrow}\ \boxed{\uparrow}\ \boxed{\uparrow}\ \boxed{\uparrow}$ ✓

b. $\boxed{\uparrow\downarrow}\ \boxed{\uparrow\downarrow}\ \boxed{\uparrow}\ \boxed{\downarrow}\ \boxed{\uparrow}$

c. $\boxed{\uparrow\downarrow}\ \boxed{\uparrow\downarrow}\ \boxed{\uparrow}\ \boxed{\downarrow}\ \boxed{\downarrow}$

d. $\boxed{\uparrow\downarrow}\ \boxed{\uparrow\downarrow}\ \boxed{\downarrow}\ \boxed{\downarrow}\ \boxed{\downarrow}$

(1999, 3M) ✓

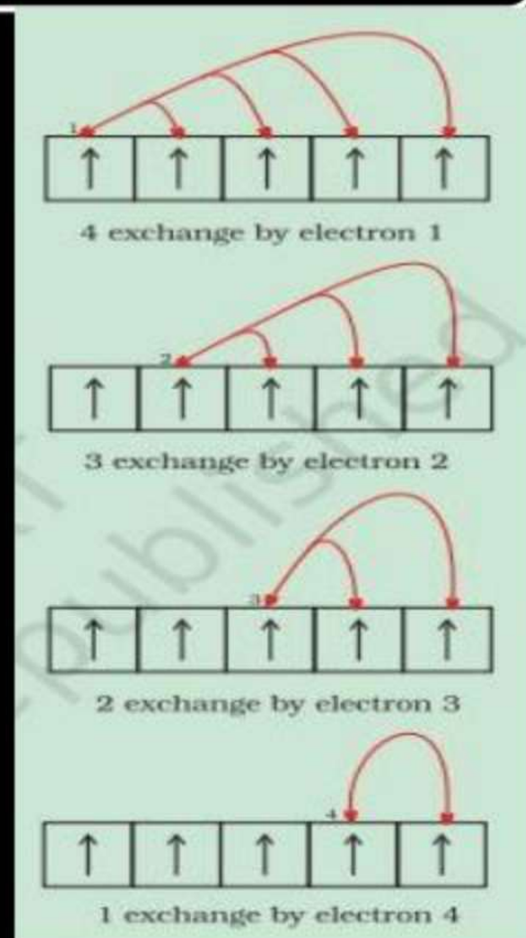
Exchange of energy

$_{24}Cr \longrightarrow [Ar]\, 4s^1\, 3d^5$

$\boxed{\uparrow \mid \uparrow \mid \uparrow \mid \uparrow \mid \uparrow}$

$_{29}Cu \longrightarrow [Ar]\, 4s^1\, 3d^{10}$

$\boxed{\uparrow\downarrow \mid \uparrow\downarrow \mid \uparrow\downarrow \mid \uparrow\downarrow \mid \uparrow\downarrow}$



Quantum no.

1.Princi Q.N (n)	2.Azimutal Q.N (l)	3.Magnetic Q.N (m) or m_l	4.Spin Q.N (s) or m_s
shell, orbit energy level n ✓	subshell, suborbit Sub energy level $l = 0$ to $n-1$ $l=0 \quad 1 \quad 2 \quad 3$ $s \quad p \quad d \quad f$	orientation $m = -l$ to $+l$ $l=0 \quad m=0$ $l=1 \quad m=-1$ to $+1$ $= -1, 0, +1$	spin $s = \pm\frac{1}{2}$

Q. Total no of orbitals in

a. $n = 3$

b. $l = 3$

Solution:

Total orbitals $= n^2$

$= 3^2$

$= 9$

Total orbitals

$= 2 \times 3 + 1$

$= 7$

max no. of orbitals $= n^2$

" " " $e^{\ominus}s = 2n^2$

max no. of orbitals $= (2l+1)$

" " " $e^{\ominus}s = 2(2l+1)$

Q. Describe the subshell

Solution:

n	l	Subshell
3	0	3s
4	1	4p
2	0	2s
3	2	3d
5	3	5f

Q. Find orbital A.M

a. 2s $l=0$ $O.A.M = \sqrt{0(0+1)}\,\hbar$ $= 0$

b. 3 P $l=1$ $\sqrt{2}\,\hbar$

$\boxed{\text{orbital } A.M = \sqrt{l(l+1)}\,\hbar}$

c. 4 d $l=2$

d. 5 f $l=3$

Solution:

$\sqrt{6}\,\hbar$

$\sqrt{12}\,\hbar$

Q. Incorrect set of quantum no.

	n	l	m	S
(a)	4	0	0	+1/2
(b)	3	1	1	–1/2
(c)	2	0	0	–1/2
(d) ✓	3	1	–2	+1/2

Solution:

$n = 4, \quad l = 0 \text{ to } n-1$
$= 0 \text{ to } 4-1$
$= 0 \text{ to } 3$
$= 0, 1, 2, 3$

$l = 0 \quad m = 0$

$l = 1 \quad m = -1, 0, +1$

$l = 2 \quad m = -2, -1, 0, +1, +2$

$l = 3 \quad m = -3, -2, -1, 0, +1, +2, +3$

Q. no. of e^-s present in d orbital?

a. 2

b. 6

c. 10

d. 14

Solution:

Q. Find the spin multiplicity and total spin if no. Upe$^-$ is 2 $\uparrow\ \uparrow$

Solution:

$SM = 2s+1$

$s = \pm\frac{2}{2}$

$s = \pm\frac{n}{2}$

$s = +1$

$s = \pm 1$

$n = $ No. of upe$^{\ominus}$

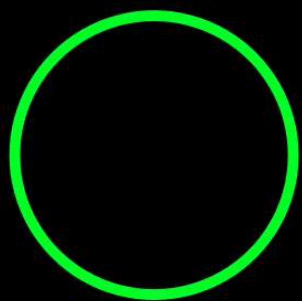
$SM = 2\times1+1$

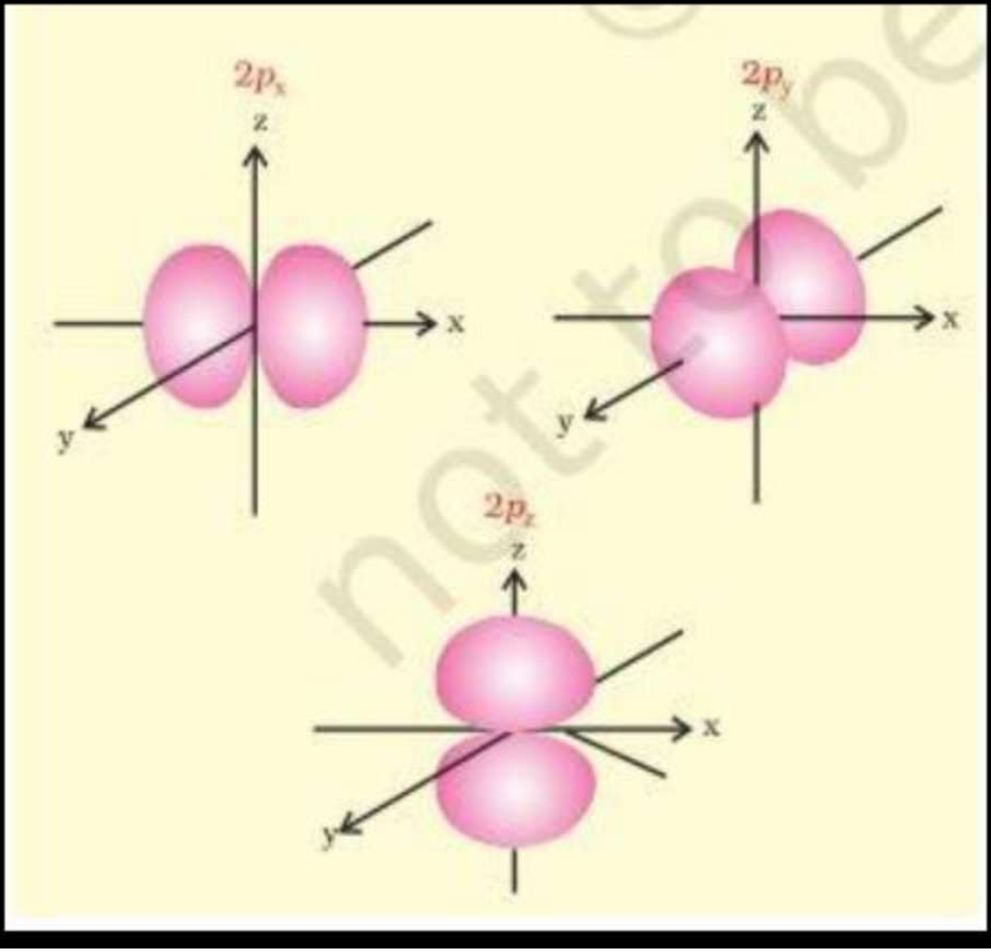
$= 3$

Shape of Orbitals

p → dumbell

S – spherical





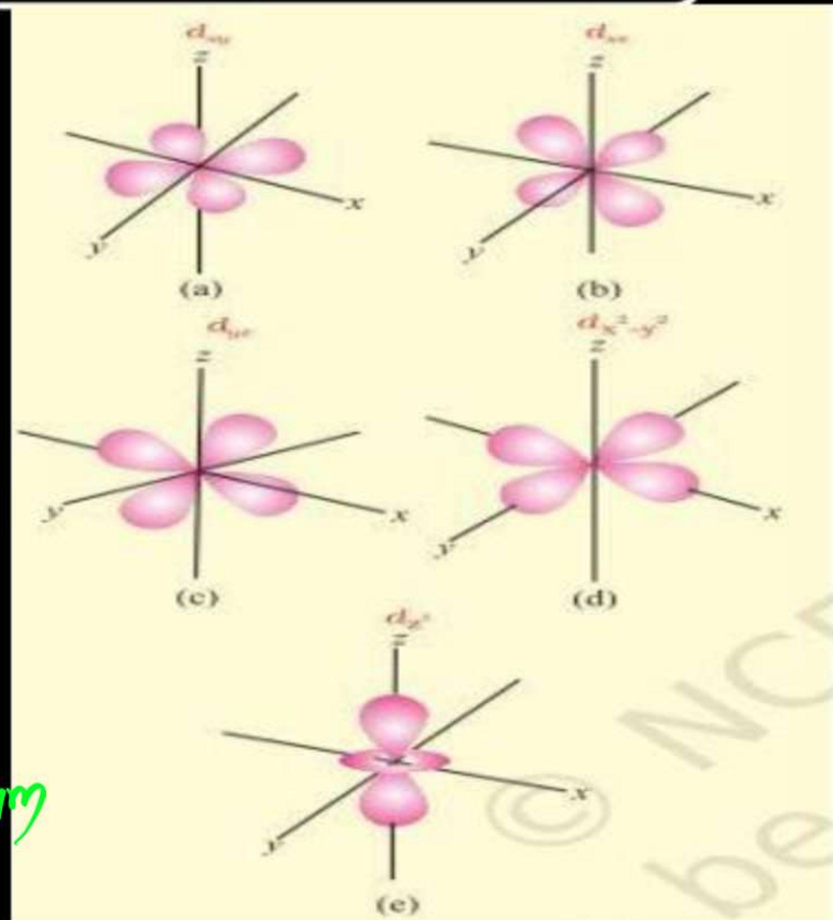
Shape of Orbitals

$d \longrightarrow$ double dumbbell

$\left.\begin{array}{l} d_{xy} \\ d_{yz} \\ d_{zx} \end{array}\right\}$ lobes lie b/w the axes 45°

$d_{x^2-y^2}$ } On the axis

d_{z^2} doughnut shape
or Baby soother diagram



Schrodinger Wave Equation

It describe the 3-D motion of $e^{\ominus}$ around Nucleus

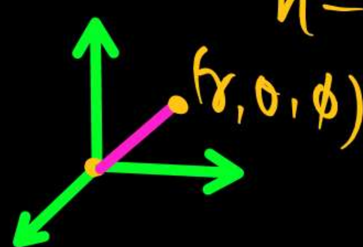
$$\frac{d^2\psi}{dx^2} + \frac{d^2\psi}{dy^2} + \frac{d^2\psi}{dz^2} + \frac{8\pi^2 m}{h^2}(E-V)\psi = 0$$

ψ = wave func^n 　 m = mass of $e^{\ominus}$ 　 E = Total energy

(x, y, z) 　 h = planck's const 　 V = potential energy

$\downarrow$

(r, θ, ϕ)



By solving this eq^n polar coordinate

1) we get diff of ψ like $\psi_1, \psi_2, \psi_3, \psi_4$ ......

2) Some of them are meaningful value known as Eigen value.

3) $$\psi(r) = \underbrace{\text{Radial part}}_{r \text{ aayega}} \times \underbrace{\text{Angular part}}_{\text{angle aayega}}$$

4) for s-orbitals

$$\psi(r) = \underbrace{\text{Radial part}}_{r \text{ aayega}}$$ angular part nahi aayega.

⑤ spin quantum no. can not be determine by schrodinger wave eq^m.

ψ_{210} → $n=2$, $l=1$, $m=0$ → $2P_z$

ψ_{300} → n, l, m → $3s$

ψ_{420} → n, l, m → $4d_{z^2}$

⑥ $\psi \longrightarrow$ There is no physical significance.

$\psi^2 \longrightarrow$ has physical significance.

Probability of find $e^\ominus$

$\psi^2 \longrightarrow$ max atomic orbital

$\psi^2 \longrightarrow$ min Node
(nearly zero)

$\rightarrow$ The space where probability of finding $e^\ominus$ is zero.

Q. The wave func^n for 2s is given by

$$\psi_{2s} = \frac{1}{2\sqrt{2}\,\pi}\left(\frac{1}{a_0}\right)^{\frac{1}{2}} \underbrace{\left[2 - \frac{r}{a_0}\right]} e^{-\frac{r}{2a_0}}$$

at $r = r_0$, radial node is formed. find r_0 in terms of a_0?

radial $\downarrow$ spherical

$$\psi_{2s}^2 = 0 \qquad 2 - \frac{r_0}{a_0} = 0$$

$$\boxed{r_0 = 2a_0}$$

Q. for 3s orbital,

$$\psi_{3s} = \frac{1}{a_0\sqrt{3}}\left(\frac{1}{a_0}\right)^{3/2}\underbrace{(6-6\sigma+\sigma^2)}\,e^{-\sigma/2}$$

where σ is $\frac{2rZ}{3a_0}$, what is the maximum radial distance of node from nucleus?

$$\sigma^2 - 6\sigma + 6 = 0$$

$$\sigma = \frac{6 \pm \sqrt{6^2 - 4\times 1\times 6}}{2\times 1}$$

$$\sigma = \frac{6 \pm \sqrt{12}}{2}$$

$$\sigma = \frac{6 \pm 2\sqrt{3}}{2}$$

$$\sigma = 3 \pm \sqrt{3}$$

$$\sigma_1 = 3 - \sqrt{3} \qquad \sigma_2 = 3 + \sqrt{3} \ \checkmark$$

$$\frac{2rZ}{3a_0} = 3+\sqrt{3}$$

$$\boxed{r = \frac{3a_0(3+\sqrt{3})}{2Z}}$$

ψ vs r

Graphs

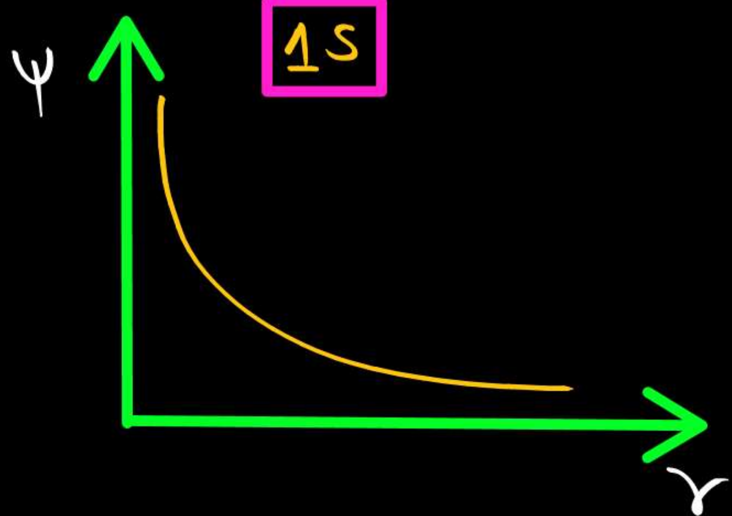
Radial node $= n - l - 1$

2s $2 - 0 - 1 = 1$

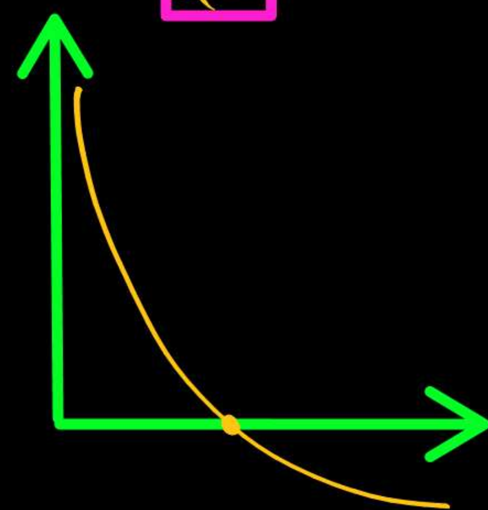
3s $3 - 0 - 1 = 2$

Case 1 for 's'

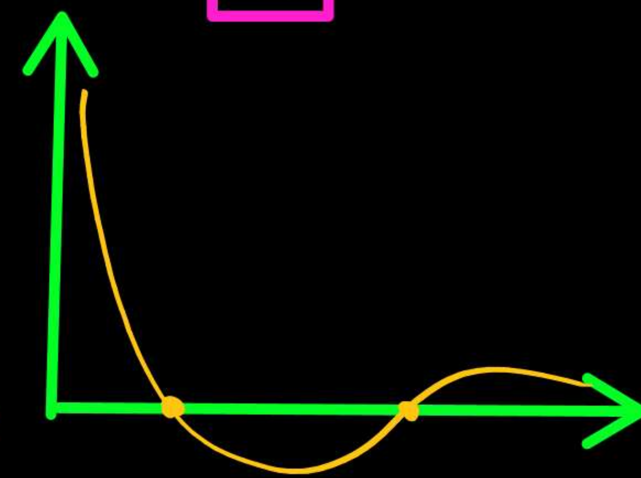
$\boxed{1s}$



$\boxed{2s}$



$\boxed{3s}$



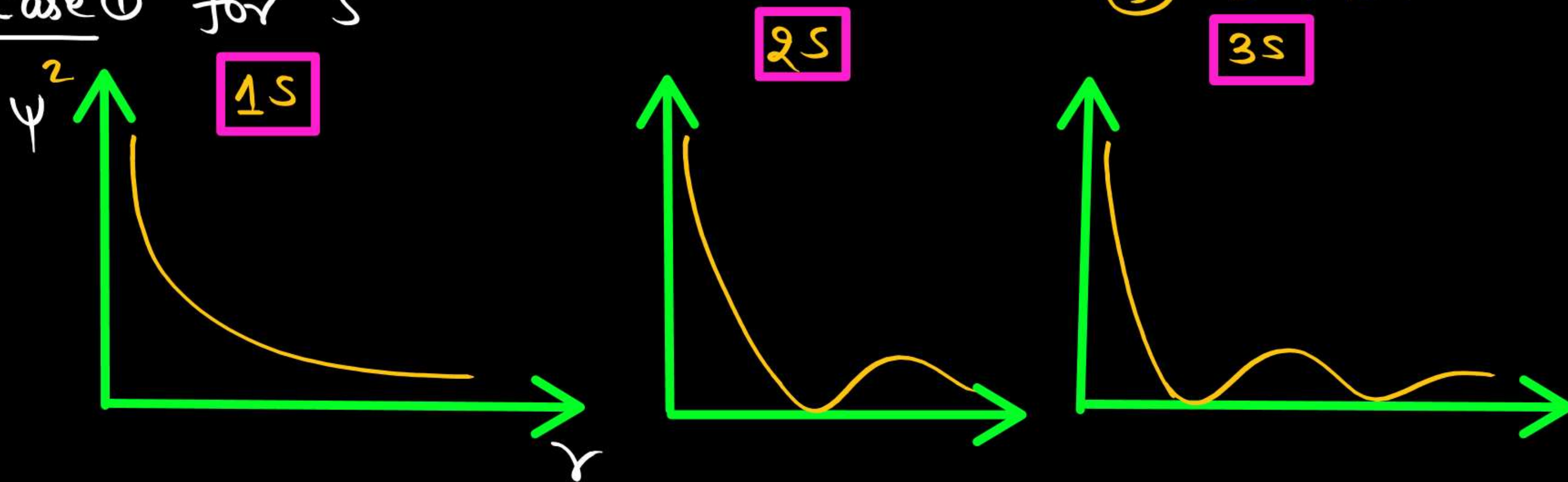
ψ^2 vs r — Graphs

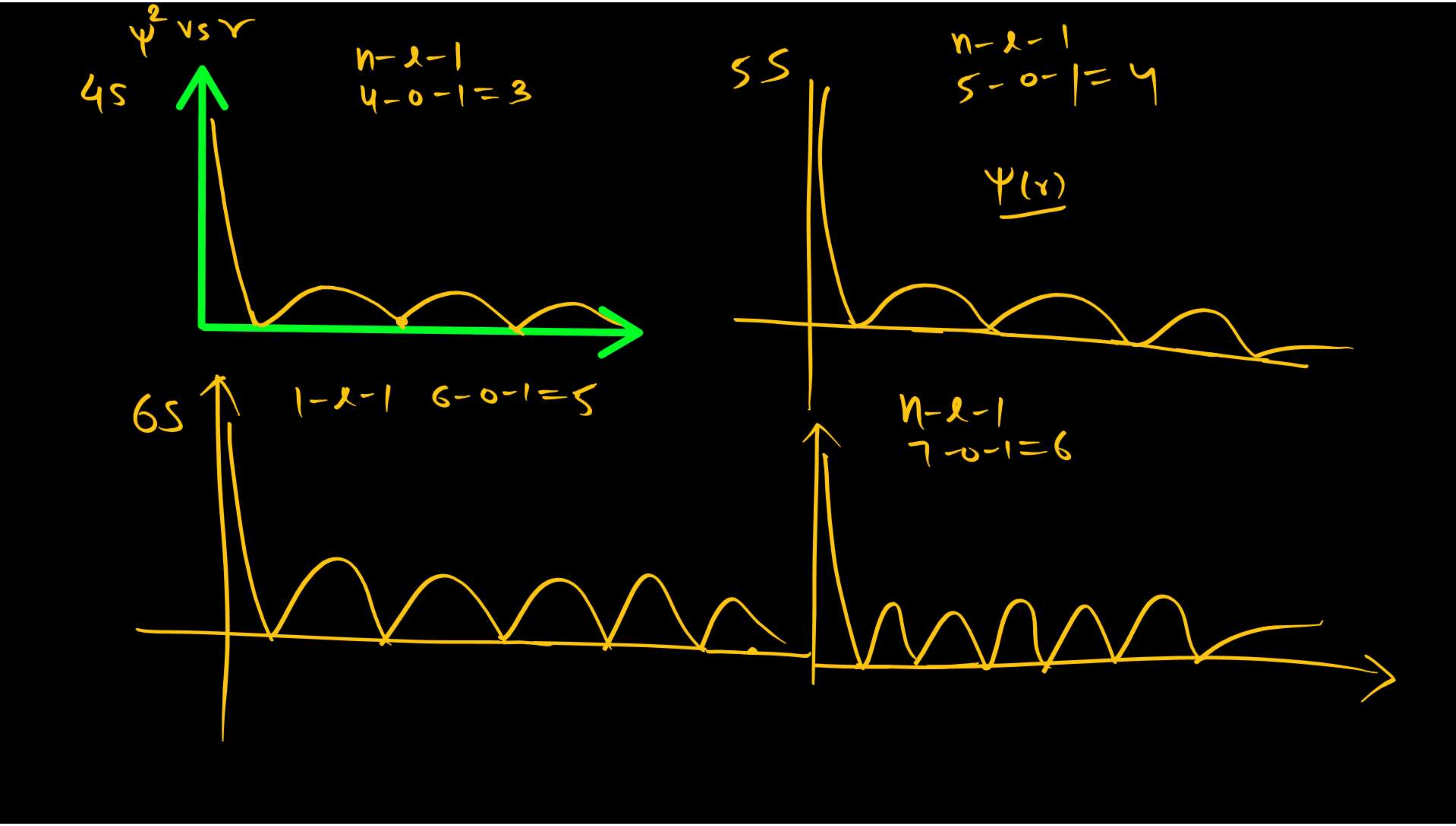
Radial node $= n - l - 1$

2s: $2 - 0 - 1 = 1$

3s: $3 - 0 - 1 = 2$

Case ① for 's'





ψ² vs r
4s
n-ℓ-1
4-0-1=3
5s
n-ℓ-1
5-0-1=4
ψ(r)
6s
1-ℓ-1
6-0-1=5
n-ℓ-1
7-0-1=6

ψ vs r

Graphs

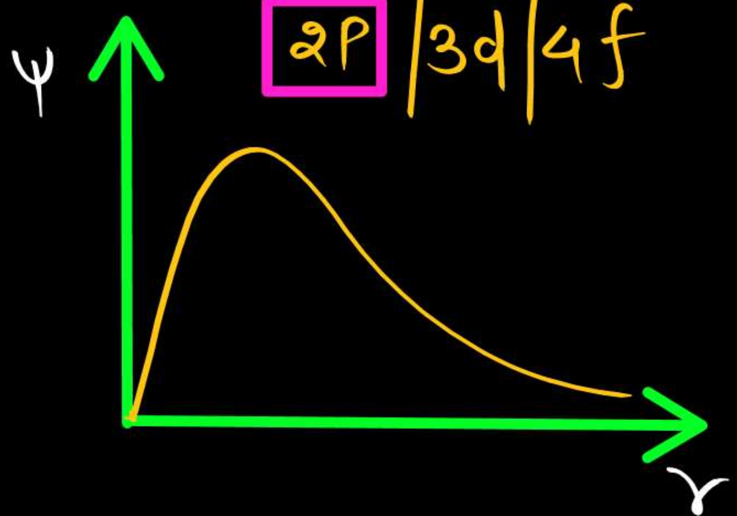
Radial node $= n - l - 1$

3p $\quad 3-1-1 = 1$

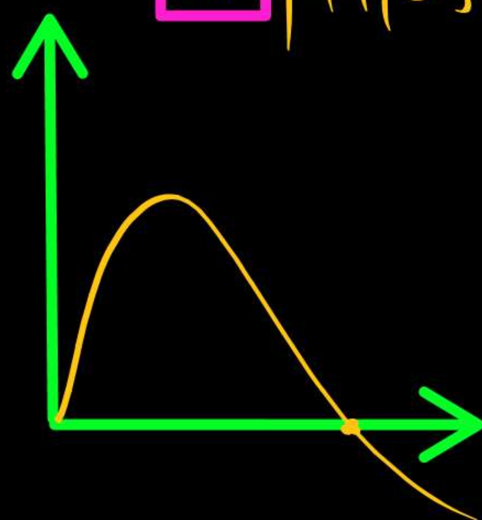
4p $\quad 4-1-1 = 2$

Case ② for p|d|f

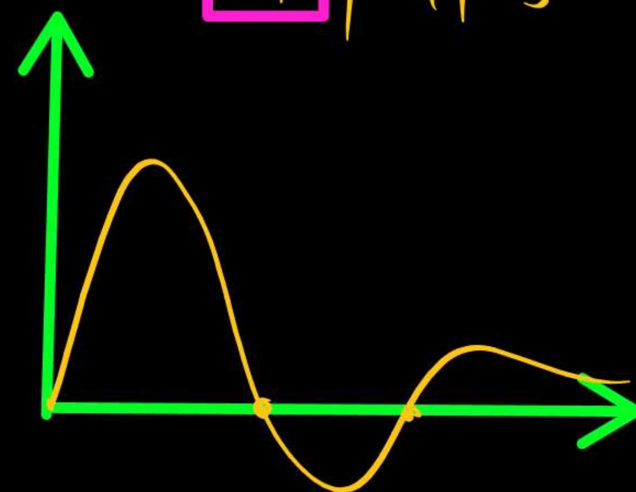
$\boxed{2p}$ | 3d | 4f



$\boxed{3p}$ | 4d | 5f



$\boxed{4p}$ | 5d | 6f



ψ^2 vs r Graphs

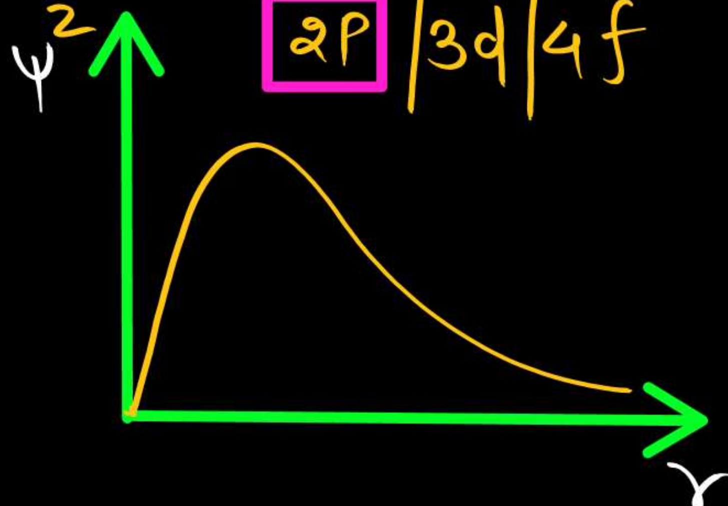
Radial node $= n - l - 1$

3p $3-1-1 = 1$

4p $4-1-1 = 2$

Case ② for p|d|f

$\boxed{2p}$ | 3d | 4f

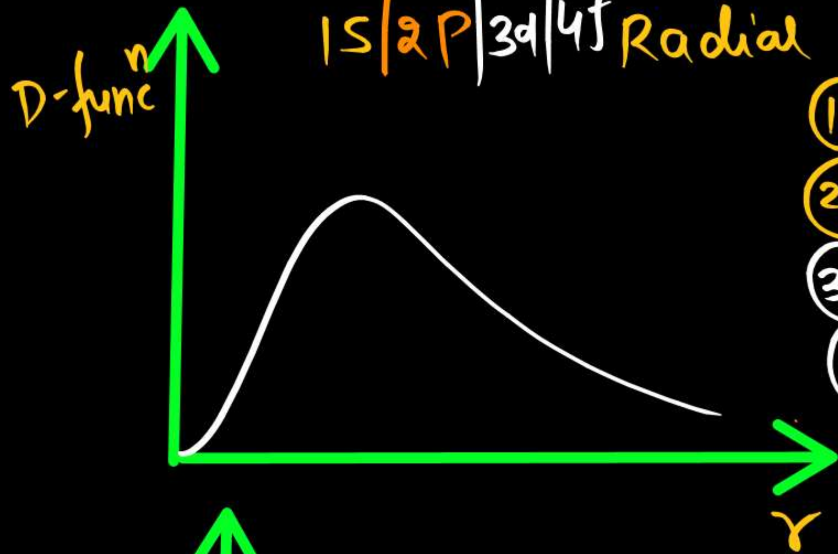


$\boxed{3p}$ | 4d | 5f

$\boxed{4p}$ | 5d | 6f

D-func^n $4\pi r^2\psi^2 dr$ (Radial probability distribution func^n)

1s|2p|3d|4f Radial node = n − l − 1

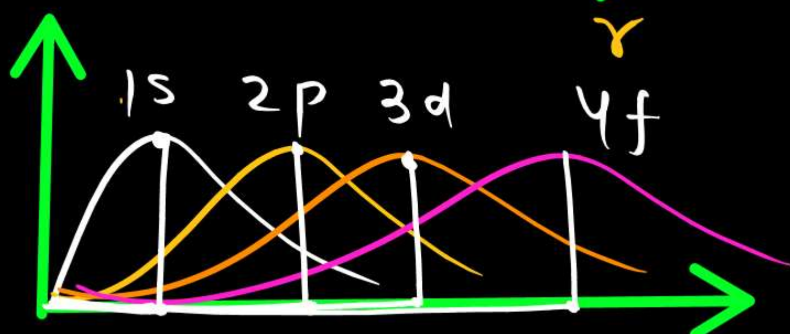


1s 1−0−1 = 0

2p 2−1−1 = 0

3d 3−2−1 = 0

4f 4−3−1 = 0

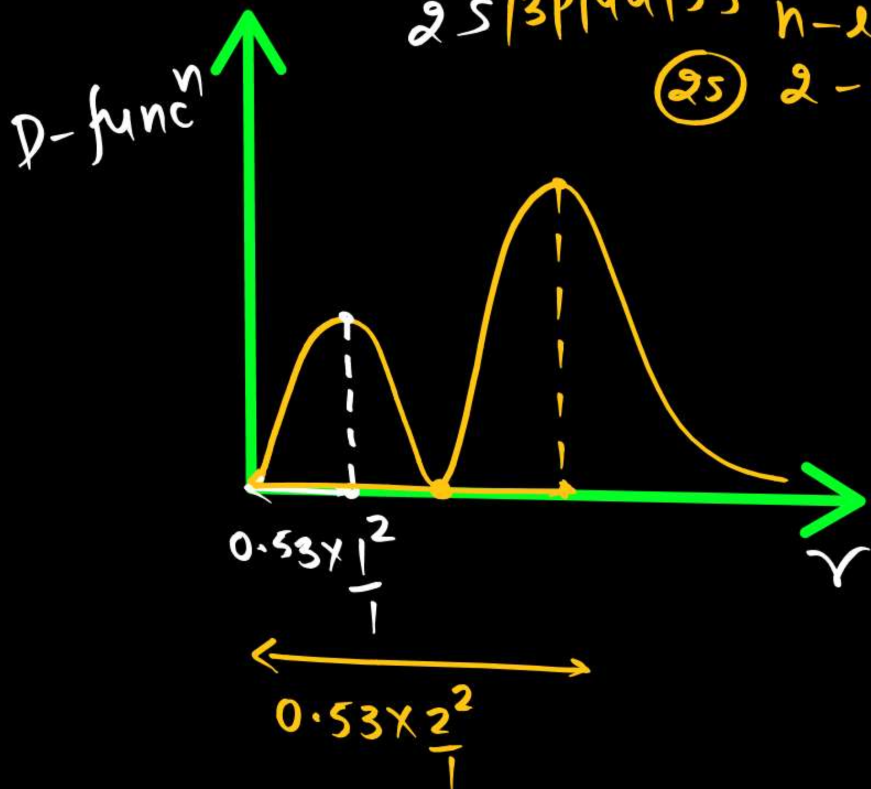


2p ψ vs r Hota hai wahi 1s ka D-func^n Hota Hai

2s | 3p | 4d | 5f

$n - l - 1$

2s: $2 - 0 - 1 = 1$

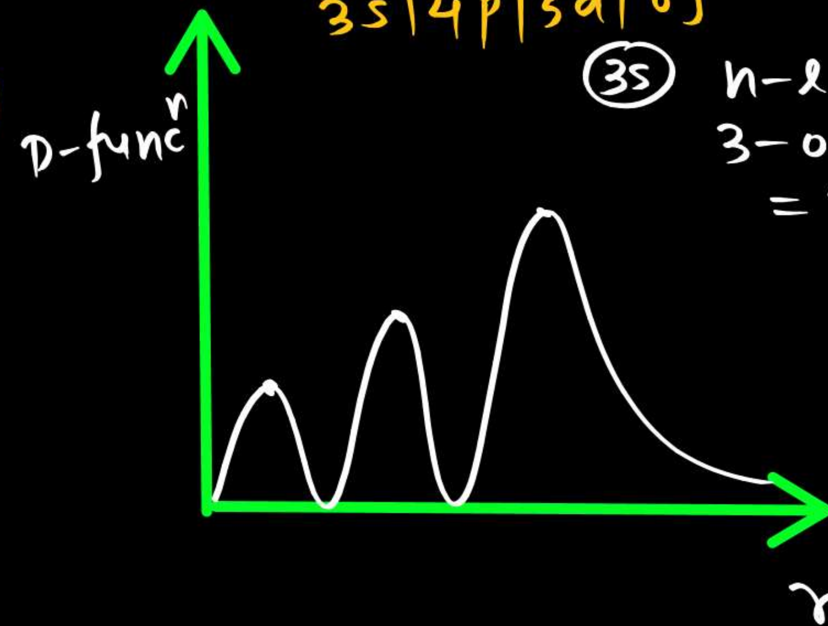


3s | 4p | 5d | 6f

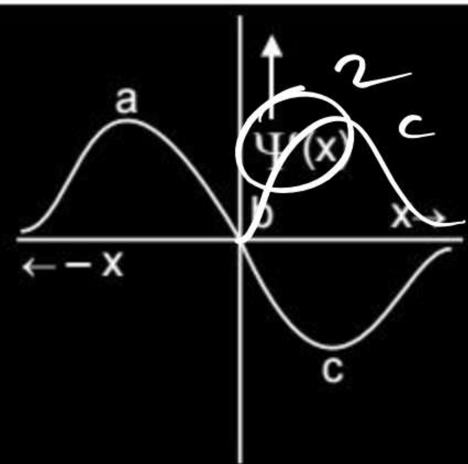
3s: $n - l - 1$

$3 - 0 - 1$

$= 2$



Q. The electrons are more likely to be found



(2019 Main 12 April I)

(a) in the region a and c

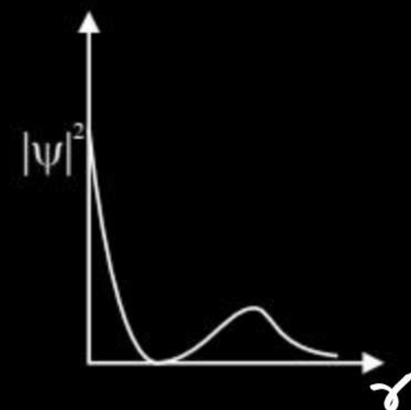
(b) in the region a and b

(c) Only in the region a

(d) Only in the region c

Q. The graph between $|\Psi|^2$ and r (radial distance) is shown below. This represents.

(2019 Main 10 April II)



(a) ls–orbital
(b) 2 p–orbital
(c) 3s–orbital
(d) 2s–orbital

Imp. Points

Total nodes = n -1 ✓

Radial or spherical nodes = n-l-1 ✓

Nodal plane = l ✓

Angular node = l ✓

Energy of subshell (Bohr burry rule or n + l rule)

Energy α $(n+l)$

if $(n+l)$ is same $E \alpha n$

Nodal plane

	Nodal plane	
s	0	
p_x	1	yz
p_y	1	zx
p_z	1	xy

d_{xy}	2
d_{yz}	2
d_{zx}	2
$d_{x^2-y^2}$	2
d_{z^2}	2 Conical nodes

Q. Find no. of Total nodes, Nodal planes, angular nodes & Radial nodes.

Subshell	T.N	R.N	N.P	A.N
3S	2	3-0-1=2	0	0
4P	3	4-1-1=2	1	1
5d	4	5-2-1=2	2	2

Q. The number of radial nodes in 3s and 2p respectively are

(a) 2 and 0
(b) 0 and 2
(c) 1 and 2
(d) 2 and 1

(2005, 1M)

$RN = n - l - 1$

$= 3 - 0 - 1 = 2$

$R.N = 2 - 1 - 1 = 0$

Q. Find magnetic moment (a) Fe^{2+} (b) Cu^{2+}

Solution:

$$M.M = \sqrt{n(n+2)}$$

n = no. of up $e^{\ominus}$s

Fe^{2+} [Ar] $4s^0 3d^6$

$n = 4$

$$MM = \sqrt{4(4+2)}$$

$$= \sqrt{24}$$

Cu^{2+} [Ar] $4s^0 3d^9$

$n = 1$

$$MM = \sqrt{1(1+2)}$$

$$= \sqrt{3}$$

Q. Compare the energy of subshell

a. 3P $(n+l) = 3+1 = 4$

b. 4S $n+l = 4+0 = 4$

c. 5d $(n+l) = 5+2 = 7$

d. 4P $n+l = 4+1 = 5$

Solution:

$$5d > 4p > 4s > 3p$$

JhamaJham Practice

Home work*

Q. Which one of the following about an electron occupying the 1s-orbital in a hydrogen atom is incorrect? (The Bohr radius is represented by a_0)

(2019 Main, 9 April II)

(a) The electron can be found at a distance $2a_0$ from the nucleus.

(b) The magnitude of the potential energy is double that of its kinetic energy on an average.

(c) The probability density of finding the electron is maximum at the nucleus.

(d) The total energy of the electron is maximum when it is at distance a_0 from the nucleus.

Q. If P is the momentum of the fastest electron ejected from a metal surface after the irradiation of light having wavelength λ, then for 1.5 P momentum of the photoelectron, then wave length of the light should be
(Assume kinetic energy of ejected photoelectron to be very high in comparison to work function)

(a) $\frac{4}{9}\lambda$

(b) $\frac{3}{4}\lambda$

(c) $\frac{2}{3}\lambda$

(d) $\frac{1}{2}\lambda$

(2019 Main, 8 April II)

Taaza-Taaza

Solution:

$E_i = \phi + KE$

$\phi =$ neglected

$\frac{hc}{\lambda} = \frac{p^2}{2m}$

$\frac{1}{\lambda} \propto p^2$

$\frac{\lambda_2}{\lambda_1} = \left(\frac{p_1}{p_2}\right)^2$

$\frac{\lambda_2}{\lambda} = \left(\frac{p}{1.5p}\right)^2$

$\lambda_2 =$

Q. A stream of electrons from a heated filament was passed between two charged plates kept at a potential difference V. If e and m are charge and mass of an electron respectively, then the value of h/λ (where, λ is wavelength associated with electron wave) is given by

(2016 Main)

a. $2\,meV$

b. $\sqrt{meV}$

c. $\sqrt{2meV}$

d. meV

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$\frac{h}{\lambda} = \sqrt{2meV}$$

Q. According to Bohr's theory,

E_n = Total energy $\quad$ K_n = Kinetic energy

V_n = Potential energy $\quad$ r^n = Radius of nth orbit

2006, 6M

$-KE = \frac{PE}{2}$

Column I		Column II
A. $V_n/K_n = ?$ (r) $\frac{V_n}{K_n} = -2$	P.	0
B. If radius of nth orbit $\propto E_n^x, x = ?$ (q) $r_n \propto E_n^{-1}$ $T.E = -\frac{kZe^2}{2r}$ $r_n \propto \frac{1}{E_n}$	q.	−1
C. Angular momentum in lowest orbital (1s) (P)	r.	−2
D. $\frac{1}{r^n} \propto Z^y, y = ?$ (S)	s.	1

$r \propto \frac{n^2}{Z}$ $\quad$ $\frac{1}{r} \propto Z$

Q. Among the following, the energy of 2s-orbital is lowest in

(a) K (b) H

(c) Li (d) Na

(2019 Main 12 April II)

Q. The ratio of the shortest wavelength of two spectral series of hydrogen spectrum is found to be about 9. The spectral series are

$\infty \to 1$ $\infty \to 3$

(a) Lyman and Paschen (b) Brackett and Pfund

(c) Pashen and Pfund (d) Balmer and Bracket

(2019 Main 10 April II)

$$\frac{1}{\lambda_1} = R_H\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) \qquad \frac{1}{\lambda_2} = R_H\left(\frac{1}{3^2} - \frac{1}{\infty^2}\right)$$

$$\lambda_1 = \frac{1}{R_H} \qquad \lambda_2 = \frac{9}{R_H}$$

$$\frac{\lambda_2}{\lambda_1} = 9$$

Q. For any given series of spectral lines of atomic hydrogen, let $\Delta\overline{v} = \overline{v}_{max} - \overline{v}_{min}$ be the difference in maximum and minimum frequencies in cm^{-1}. The ratio $\Delta\overline{v}_{Lyman} / \Delta\overline{v}_{Balamer}$

(a) $27 : 5$
(b) $5 : 4$
(c) $9 : 4$
(d) $4 : 1$

(2019 Main 9 April I)

Q. The quantum number of four electrons are given below :

(I) $n = 4, l = 2, m_l = -2, m_s = -\frac{1}{2}$

$n+l = 4+2 = 6$

(II) $n = 3, l = 2, m_l = 1, m_s = +\frac{1}{2}$

$n+l = 3+2 = 5$

(III) $n = 4, l = 1, m_l = 0, m_s = +\frac{1}{2}$

$n+l = 4+1 = 5$

(IV) $n = 3, l = 1, m_l = 1, m_s = -\frac{1}{2}$

$n+l = 3+1 = 4$

The correct order of their increasing energy will be

(a) IV < III < II < I

(b) I < II < III < IV

(c) IV < II < III < I

(d) I < III < II < IV

(2019 Main 8 April I)

The work function (ϕ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300 nm wavelength falls on the metal is

3000 Å

Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
Φ(eV)	2.4 ✓	2.3 ✓	2.2 ✓	3.7 ✓	4.8	4.3	4.7	6.3	4.75

Solution:

$\nu > \nu_0$

$E_i > \phi$

$E_i = \frac{12400}{\lambda(Å)}$ eV

$E_i = \frac{12400}{3000}$ eV

$E_i = 4.13$ eV

JEE Adv 2011

Ans 4

Q. The de-Broglie wavelength (λ) associated with a photoelectron varies with the frequency (ν) of the incident radiations as, [ν_0 is threshold frequency]

(2019 Main 11 Jan II)

$\underbrace{\hphantom{(2019 Main 11 Jan II)}}_{\text{Taaza-Taaza}}$

(a) $\lambda \propto \dfrac{1}{(\nu-\nu_0)^{\frac{1}{4}}}$

(b) $\lambda \propto \dfrac{1}{(\nu-\nu_0)^{\frac{3}{2}}}$

(c) $\lambda \propto \dfrac{1}{(\nu-\nu_0)}$

(d) $\lambda \propto \dfrac{1}{(\nu-\nu_0)^{\frac{1}{2}}}$ ✓

$E_i = \phi + KE$

$h\nu = h\nu_0 + KE$

$KE = h\nu - h\nu_0$

$KE \propto (\nu-\nu_0)$

$\dfrac{1}{\lambda^2} \propto (\nu-\nu_0)$

$\lambda^2 \propto \dfrac{1}{(\nu-\nu_0)}$

$\lambda \propto \dfrac{1}{(\nu-\nu_0)^{1/2}}$

$\lambda = \dfrac{h}{\sqrt{2mKE}}$ $\quad \lambda \propto \dfrac{1}{\sqrt{KE}}$ $\quad \lambda^2 \propto \dfrac{1}{KE}$

Q. Which of the following combination of statements is true regarding the interpretation of the atomic orbitals?

(I) An electron in an orbital of high angular momentum stays away from the nucleus than an electron in the orbital of lower angular momentum.

(II) For a given value of the principal quantum number, then size of the orbit is inversely proportional to the azimuthal quantum number.

(III) According to wave mechanics, then ground state angular momentum is equal to $\frac{h}{2\pi}$

(IV) The plot of Ψ vs r for various azimuthal quantum numbers, shows peak shifting towards higher r value.

(2019 Main 11 Jan I)

(a) I, III
(b) II, III
(c) I, II
(d) I, IV

Q. Heat treatment of muscular pain involves radiation of wavelength of about 900 nm. Which spectral line of H-atom is suitable for this purpose ? [$R_H = 1 \times 10^5\ cm^{-1}$, $h = 6.6 \times 10^{-34}$ Js, $c = 3 \times 10^8\ ms^{-1}$]

(2019 Main 11 Jan I)

(a) Paschen, $5 \rightarrow 3$

(b) Paschen, $\underline{\infty \rightarrow} 3$

(c) Lyman, $\infty \rightarrow 1$

(d) Balmer, $\infty \rightarrow 2$

$$\frac{1}{\lambda} = R_H (1)^2 \left(\frac{1}{3^2} - \frac{1}{\infty^2} \right)$$

$$\lambda = \frac{9}{R_H}$$

$$\lambda = \frac{9}{10^5}\ cm = 9 \times 10^{-5}\ cm$$

Q. For emission line of atomic hydrogen from $n_i = 8$ to $n_f = n$, the plot of wave number $(\bar{\nu})$ against $\left(\frac{1}{n^2}\right)$ will be (The Rydberg constant, R_H is in wave number unit)

(2019 Main 09 Jan I)

(a) non linear
(b) linear with slope – RH
(c) linear with slope RH
(d) linear with intercept – RH

$$\bar{\nu} = R_H (1)^2 \left[\frac{1}{8^2} - \frac{1}{n^2}\right]$$

$$\bar{\nu} = \frac{R_H}{64} - \frac{R_H}{n^2}$$

$$y = c - mx$$

Q. The radius of the second Bohr orbit for hydrogen atom is (Planck's constant (h) = 6.6262×10^{-34} Js; mass of electron = 9.1091×10^{-31} kg ; charge of electron
(e) = 1.60210×10^{-19} C; premitivity of vaccum
($\in_0$ 8.854185×10^{-12} kg^{-1} $m^{-3}A^2$)

(a) 1.65 Å
(b) 4.76 Å
(c) 0.529 Å
(d) 2.12 Å

(2017 Main)

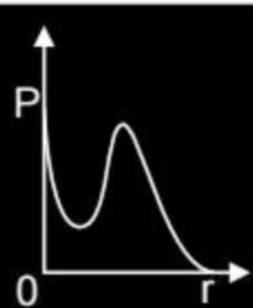
$$r = a_0 \times \frac{n^2}{Z}$$

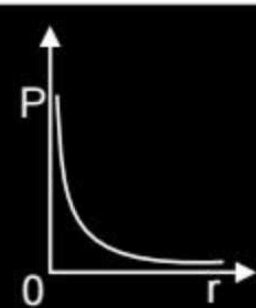
$$r = a_0 \times 2^2$$

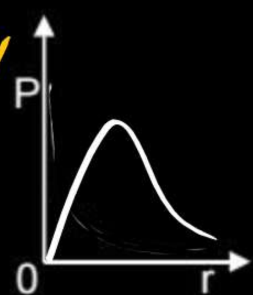
$$r = 4a_0 = 4 \times 0.53$$

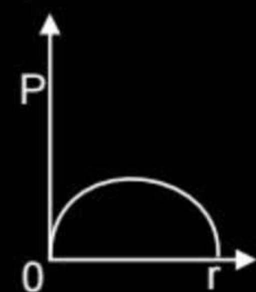
Q. **P is the probability of finding the 1s electron of hydrogen atom in a spherical shell of infinitestimal thickness, dr, at a distance r from the nucleus. The volume of this shell is $4\pi r2dr$. The qualitative sketch of the dependence of P on r is**

(2016 Adv.)

(a) 

(b) 

(c) 

(d) 

Q. The correct set of four quantum numbers for the valence electrons of rubidium atom (Z = 37) is

(2013 Main)

(a) $5, 0, 0, +\frac{1}{2}$

(b) $5, 1, 0, +\frac{1}{2}$

(c) $5, 1, ,1, +\frac{1}{2}$

(d) $5, 0, 1, +\frac{1}{2}$

Q. Energy of an electron is given by

$E = -2.178 \times 10^{-18}\ \mathrm{J}\left(\dfrac{Z^2}{n^2}\right)$

Wavelength of light required to excite an electron in an hydrogen atom from level n = 1 to n = 2 will be

$Z = 1$

($h = 6.62 \times 10^{-34}$ Js and $c = 3.0 \times 10^{8}\ \mathrm{ms^{-1}}$)

(a) 1.214×10^{-7}m

(b) 2.816×10^{-7}m

(c) 6.500×10^{-7}m

(d) 8.500×10^{-7}m

(2013 Main)

$$\frac{1}{\lambda} = R_H (1)^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right] \qquad \lambda = \frac{4}{3 \cdot 3 \times 10^7}$$

$$\frac{1}{\lambda} = 1.1 \times 10^7 \times \frac{3}{4}$$

Q. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius]

$n = 2$ $\quad$ $z = 1$

2012

JEE Adv

(a) $\frac{h^2}{4\pi^2 m a_0^2}$

(b) $\frac{h^2}{16\pi^2 m a_0^2}$

(c) $\frac{h^2}{32\pi^2 m a_0^2}$

(d) $\frac{h^2}{64\pi^2 m a_0^2}$

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

$mv a_0 \times \frac{n^2}{z} = \frac{nh}{2\pi}$

$mv a_0 \times \frac{2}{1} = \frac{h}{2\pi}$

$v = \frac{h}{4\pi m a_0}$

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

$= \frac{1}{2} \cancel{m} \frac{h^2}{16\pi^2 m^{\cancel{2}} a_0^2}$

$= \frac{h^2}{32\pi^2 m a_0^2}$

Q. Which hydrogen like species will have same radius as that of Bohr orbit of hydrogen atom? a_0

$z^2=4$ $z=4$

(a) $n = 2, Li^{2+}$

(b) $n = 2, Be^{3+}$

(c) $n = 2, He^{+}$

(d) $n = 3, Li^{2+}$

(2004, 1M)

$r = a_0 \times \frac{n^2}{z}$ $n^2 = z$

Q. If the nitrogen atom had electronic configuration $1s^7$, it would have energy lower than that of the normal ground state configuration $1s^2\ 2s^2\ 2p^3$, because the electrons would be closer to the nucleus, yet $1s^7$ is not observed, becase it violates.

(2002, 3M)

(a) Heisenberg uncertainty principle
(b) Hund's rule
(c) Pauli exclusion principle
(d) Bohr postulate of stationary orbits

$\boxed{}$ $2e^{\ominus}$

Q. The quantum numbers $+\frac{1}{2}$ and $-\frac{1}{2}$ for the electron spin represent

(2001, 1M)

a. rotation of the electron in clockwise and anti–clockwise direction respectively

b. rotation of the electron in anti–clockwise and clockwise direction respectively

c. magnetic moment of the electron pointing up and down respectively

d. two quantum mechanical spin states which have no classical analogue

Solution:

Q. The electronic configuration of an element is $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$. This represents its

Cr

a. excited state

b. ground state

(2000, 1M)

c. cationic form

d. anionic form

Solution:

Q. For a *d*-electron the orbital angular momentum is $\sqrt{l(l+1)}\,\hbar$

$l = 2$

a. $\sqrt{6}\left(\frac{h}{2\pi}\right)$

b. $\sqrt{2}\left(\frac{h}{2\pi}\right)$

(1997, 1M)

c. $\left(\frac{h}{2\pi}\right)$

d. $2\left(\frac{h}{2\pi}\right)$

Solution:

Q. Which of the following has the maximum number of unpaired electrons?

(1996, 1M)

a. Mg^{2+} $1s^2, 2s^2, 2p^6$
zero UP e^{-}s

b. Ti^{3+}
[Ar] $3d^1$

c. V^{3+} [Ar] $3d^2$
2

d. Fe^{2+} [Ar] $3d^6$

Solution:

Q. The orbital angular momentum of an electron in 2s-orbital is

a. $+\frac{1}{2}\cdot\frac{h}{2\pi}$

b. zero

(1996, 1M)

c. $\frac{h}{2\pi}$

d. $\sqrt{2}\cdot\frac{h}{2\pi}$

Solution:

Q. The correct set of quantum numbers for the unpaired electron of chlorine atom is

(1989, 1M)

	n	l	m
a.	2	1	0
b.	2	1	1
c.	3	1	1
d.	3	0	0

Solution: $_{17}Cl$ $1s^2\,2s^2\,2p^6\,3s^2\,3p^5$ $3p$

$\boxed{\uparrow\downarrow \mid \uparrow\downarrow \mid \uparrow}$ $n=3,\ l=1$

$\pm1 \quad 0 \quad \pm1$

Q. The correct ground state electronic configuration of chromium atom is

(1989, 1M)

a. $[Ar]3d^5 4s^1$

b. $[Ar]3d^4 4s^2$

c. $[Ar]3d^6 4s^0$

d. $[Ar]4d^5 4s^1$

Solution:

Q. The outermost electronic configuration of the most electronegative element is

F

a. ns^2np^3

b. ns^2np^4

(1988, 90, 1M)

c. ns^2np^5

d. ns^2np^6

Solution:

Q. The orbital diagram in which the Aufbau principle is violated

a. $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{}$

b. $\boxed{\uparrow}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}$

c. $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

d. $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow}$

(1988, 1M)

Solution:

Q. The wavelength of a spectral line for an electronic transition is inversely related to

$\frac{1}{\lambda} \propto \frac{1}{n_1^2} - \frac{1}{n_2^2}$

(1988, 1M)

a. the number of electrons undergoing the transition

b. the nuclear charge of the atom

c. the difference in the energy of the energy levels involved in the transition

d. the velocity of the electron undergoing the transition

Q. The ratio of the energy of a photon of 2000Å wavelength radiation to that of 4000 Å radiation is

(1986, 1M)

a. $\frac{1}{4}$

b. 4

c. $\frac{1}{2}$

d. 2.

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

$\frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$

$= \frac{4000}{2000}$

$= 2$

Q. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon?

a. 3s

b. 2p

(1984, 1M)

c. 2s

d. 1s

Q. Correct set of four quantum numbers for the valence (outermost) electron of rubidium ($Z = 37$) is

(1984, 1M)

a. $5, 0, 0, +\frac{1}{2}$

b. $5, 1, 0, +\frac{1}{2}$

c. $5, 1, 1, +\frac{1}{2}$

d. $6, 0, 0, +\frac{1}{2}$

$Z = 37$ $[Ar]4s^2 3d^{10} 4p^6 5s^1$

$n = 5, l = 0, m = 0, s = +\frac{1}{2}$

Q. The principal quantum number of an atom is related to the

a. size of the orbital

b. spin angular momentum

$\sqrt{s(s+1)}\,\hbar$

c. orientation of the orbital in space

d. orbital angular momentum

(1983, 1M)

Q. Any *p*-orbital can accommodate upto

a. four electrons

b. six electrons (1983, 1M)

c. two electrons with parallel spins

d. two electrons with opposite spins

$\boxed{\uparrow\downarrow}$

S_1 $n-l-1=1$

S_2 $n-l-1=1$

Passage Based Questions

The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2. The state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom.

S_2 $E = -13.6 \times \frac{z^2}{n^2}$ $n=3$

$z = n$

Q. The state S_1 is

a. 1s

b. 2s

2010

c. 2p

d. 3s

$l = 0$

$n - l - 1 = 1$

$n - 0 - 1 = 1$

$n = 2$

2s

Q. Energy of the state S1, in units of the hydrogen atom ground state energy is

a. 0.75

b. 1.50

2010

c. 2.25

d. 4.50

2s

$n = 2, z = 3$

$$E = -13.6 \times \frac{3^2}{2^2}$$

$$E = -13.6 \times \frac{9}{4}$$

$$E = \frac{9}{4} E_H$$

Q. The orbital angular momentum quantum number of the state S_2 is

l

a. 0

b. 1

2010

c. 2

d. 3

$n - l - 1 = 1$

$3 - l - 1 = 1$

$l = 3 - 1 - 1$

$l = 1$

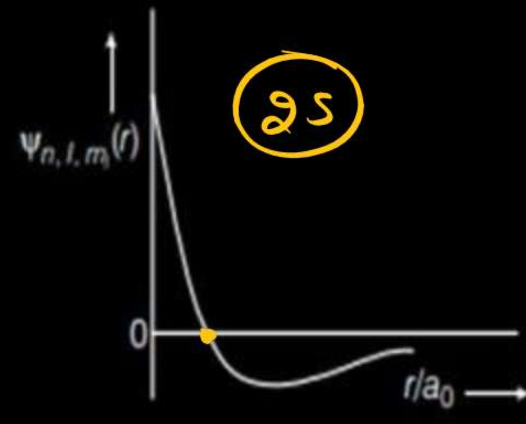
3p

Match the Columns

Answer Q. 52, Q. 53 and Q. 54 by appropriately matching the information given in the three columns of the following table.

The wave function, ψ_{n}, l, m_l is a mathematical function whose value depends upon spherical polar coordinates (r, θ, ϕ) of the electron and characterised by the quantum number n, l and m_l. Here r is distance from nucleus, θ is colatitude and ϕ is azimuth. In the mathematical functions given in the Table, Z is atomic number and a_0 is Bohr radius.

2017 Adv.

Column 1	Column 2	Column 3
(I) 1s-orbital	(i) $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} e^{-\left(\frac{Zr}{a_0}\right)}$ z = 1	(P)  2s
(II) 2s-orbital	n - l - 1 = 2 - 0 - 1 = 1 (ii) One radial node	(Q) Probability density at nucleus $\propto \frac{1}{a_0^3}$
(III) $2p_z$-orbital	(iii) $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{5}{2}} re^{-\left(\frac{Zr}{a_0}\right)} \cos\theta$	(R) Probability density is maximum at nucleus
(IV) $3d_{z^2}$-orbital	(iv) xy-plane is a nodal plane	(S) Energy needed to excite electron from $n = 2$ state to $n = 4$ state is $\frac{27}{32}$ times the energy needed to excite electron from $n = 2$ state to $n = 6$ state

$$\Delta E \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\frac{(\Delta E)_2}{(\Delta E)_1} = \frac{\left(\frac{1}{n_1'^2} - \frac{1}{n_2'^2}\right)}{\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)} = \frac{\frac{1}{4} - \frac{1}{16}}{\frac{1}{4} - \frac{1}{36}} = \frac{27}{32}$$

Q. For He^{+} ion, the only INCORRECT combination is

a. (I) (i) (S) ✗

b. (II) (ii) (Q)

c. (I) (iii) (r)

d. (I) (i) (R)

Q. For the given orbital in Column 1, the Only CORRECT combination for any hydrogen-like species is

a. (II) (ii) (P)

b. (I) (ii) (S)

c. (IV) (iv) (R)

d. (III) (iii) (P)

Q. For hydrogen atom, the only CORRECT combination is

a. (I) (i) (P)

b. (I) (iv) (R)

c. (II) (i) (Q)

d. (I) (i) (S)

Not considering the electronic spin, the degeneracy of the second excited state ($n = 3$) of H-atom is 9, while the degeneracy of the second excited state of H^- is 3

degenerated orbitals

$2e^-$

2015 Adv.

Solution:

Energy for H $1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f$

$1 < 2 < 3 < 4 < \dots$

Energy other than H $1s < 2s < 2p < 3s < 3p < 4s < 3d \dots$

1st Es 2nd Es

In an atom, the total number of electrons having quantum numbers

$$n = 4, |m_l| = 1 \text{ and } m_s = -\frac{1}{2} \text{ is}$$

$m_l = \pm 1$

2014 Adv.

Solution: $n = 4$

$\cancel{4s}$ $4p$ $4d$ $4f$

$m = 0$ 4 4 4

$s = \pm\frac{1}{2} \leftarrow 12$ total

$s = -\frac{1}{2}$ 6

The atomic masses of He and Ne are 4 and 20 amu, respectively. The value of the de-Broglie wavelength of He gas at –73°C is '*M*' times that of the de-Broglie wavelength of Ne at 727°C. *M* is

2013 Adv.

Solution:

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

$$KE = \frac{3}{2}KT$$

$$\lambda = \frac{h}{\sqrt{2m\frac{3}{2}KT}}$$

$$\lambda = \frac{h}{\sqrt{2mKT}}$$

$$\lambda \propto \frac{1}{\sqrt{mT}}$$

$$\lambda_{He} = M\,\lambda_{Ne}$$

$$\frac{\lambda_{He}}{\lambda_{Ne}} = M$$

$$\sqrt{\frac{M_{Ne}T_{Ne}}{M_{He}T_{He}}} = M$$

$$\sqrt{\frac{20 \times 1000}{4 \times 200}} = M$$

$$M = 5$$

The maximum number of electrons that can have principal quantum number, $n = 3$ and spin quantum number, $m_s = -1/2$, is

$2n^2$

2011

Solution:

$n = 3$ $\quad 2 \times 3^2 = 18$

$18 \rightarrow 9 \quad s = +\frac{1}{2}$

$18 \rightarrow 9 \quad s = -\frac{1}{2}$

9