PRACHAND NEET

ONE SHOT

Day-2

CHEMISTRY

Structure of Atom



By – Sudhanshu Sir

Topics *to be covered*

1. Discovery of sub-atomic particles
2. Atomic Models
3. Scientific developments in b/w Models
4. Quantum Numbers and its application



PRACHAND SERIES

TELEGRAM CHANNEL



① Mole Concept ✓✓

② Structure of Atom → Inorganic chemistry

- Periodic
- Chemical Bonding

Introduction

Na^+ → Relative charge = +1
→ exact charge = $+1 \times 1.6 \times 10^{-19} C$

- The atomic theory of matter was first proposed by John Dalton, known as Dalton's atomic theory.
- Dalton regarded that atom is the ultimate particle of matter.
- According to Modern Atomic Theory, atoms can be further divided into subatomic particles i.e. electrons, protons and neutrons

Z = Atomic No = no. of protons
A = Mass No = no. of nucleons (protons + neutrons)
no. of $e^{\ominus}$ = no. of protons → for neutral atom



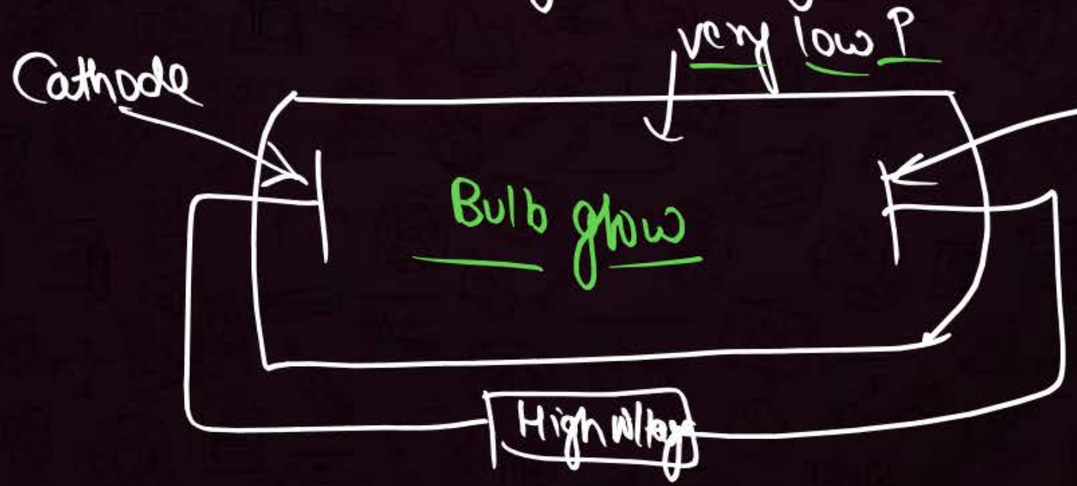
Discovery of Sub-Atomic Particles

- electrons
- protons
- Neutrons

Crook → Air ≠ bad conductor of electricity

→ Show conductivity at very low Pressure and high voltage

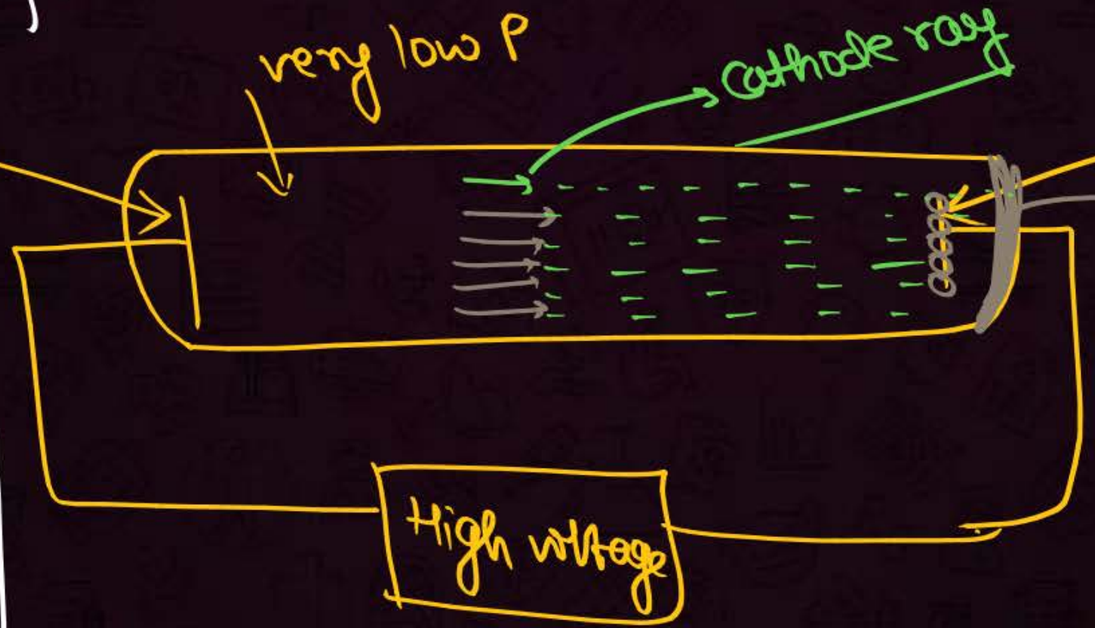
Faraday → discharge tube

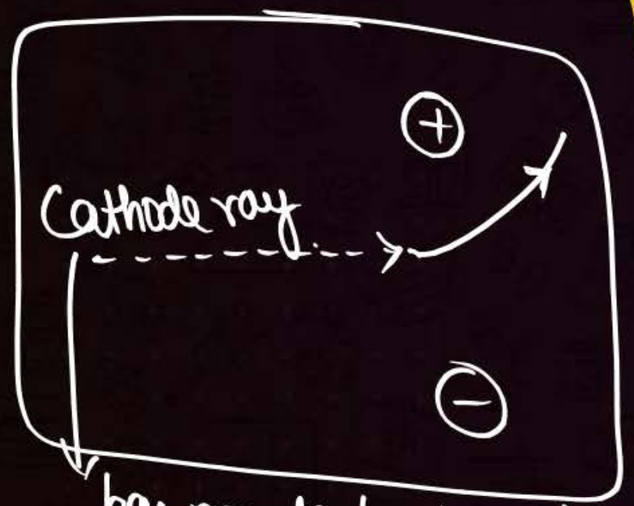


Cathode ray experiment ⇒ By J.J. Thomson

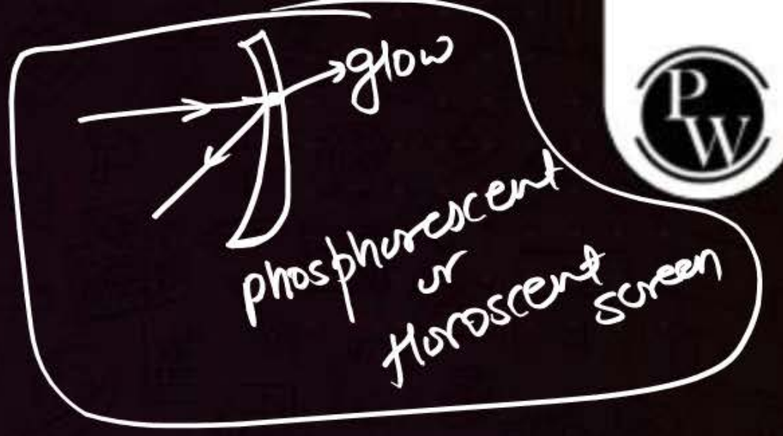
Floroscent screen → ZnS

discharge tube with prefurated anode and floroscent screen behind anode.





has negatively charged particles known as Negatrons or electrons



very low P & High voltage

↓

gases ionises.

$H_2 \rightarrow 2H^{+} + 2e^{-}$

$2e^{-}$ → Cathode ray

Properties of Cathode Rays

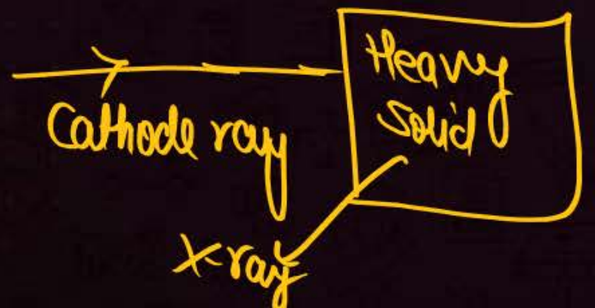
- The cathode rays start from cathode and move towards the anode.
- The cathode rays are not visible but their behaviour can be observed with the help of **fluorescent** or **phosphorescent** materials.
- In the absence of electrical or magnetic field, cathode rays **travel in straight lines.**
- In the presence of electrical or magnetic field, the behaviour of cathode rays are similar to that expected from negatively charged particles, suggesting that the cathode rays consist of **negatively charged particles,** called electrons.

Properties of Cathode Rays

- The characteristics of cathode rays **do not depend** upon the material of electrodes and the nature of the gas present in the cathode ray tube.
- Cathode rays consist of negatively charged particles known as electron.
- Cathode rays travel with high speed approaching that of light (ranging between ~~10^8 and 10^{11} cm/sec~~).

C = speed of light = 3×10^8 m/s

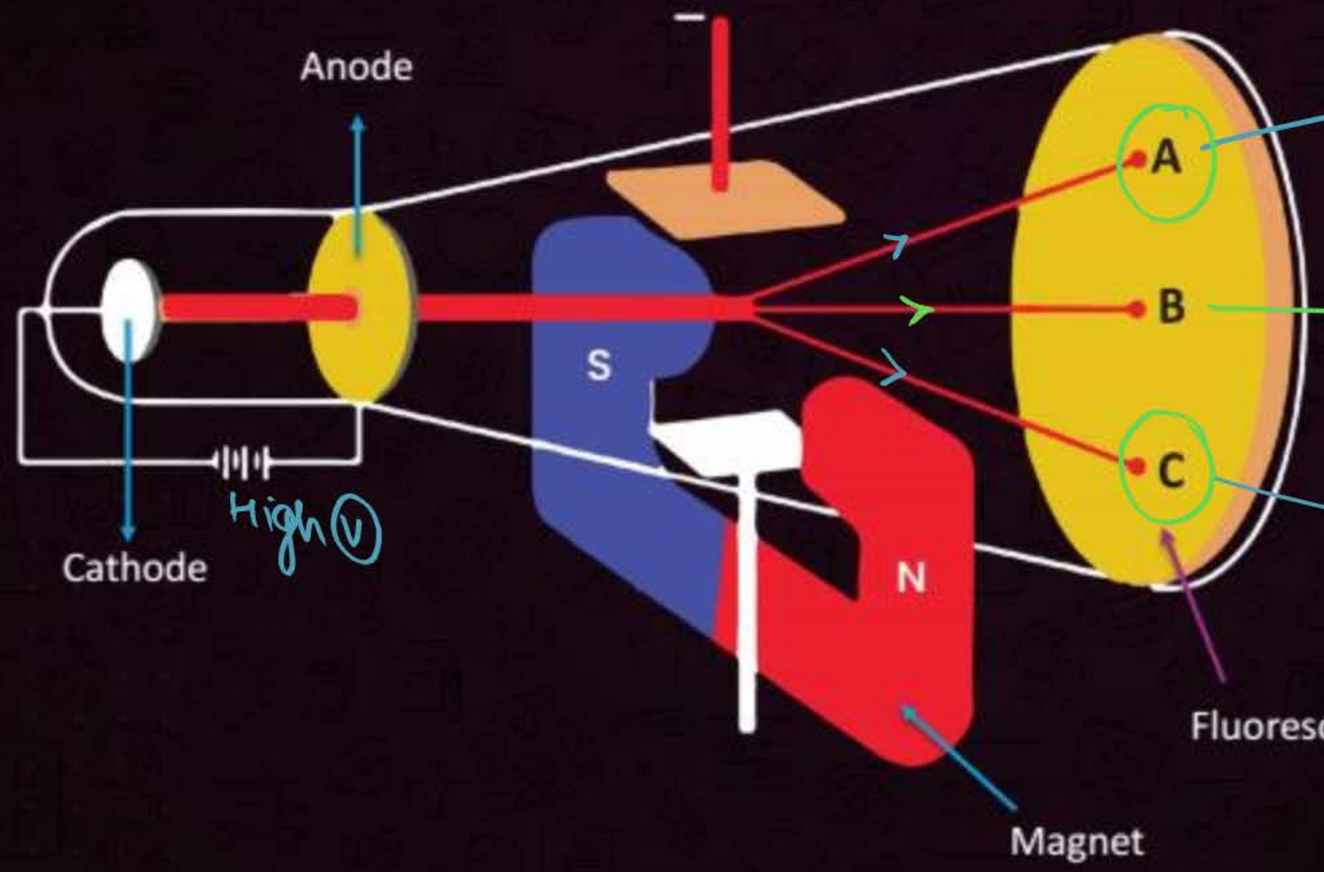
- Cathode rays can cause fluorescence.
- Cathode rays heat the object on which they fall due to transfer of kinetic energy to the object.
- When cathode rays fall on Heavy solids, X-rays are produced.



Charge to Mass Ratio of Electron

$\frac{(e)\text{charge}}{(m)\text{mass}}$ = specific charge

The apparatus to determine the charge to the mass ratio of electron:



$\vec{F} = q\vec{E}$

in presence of electric field ($\vec{E}$)

in balanced ($\vec{E}$ & $\vec{B}$)

in presence of magnetic field ($\vec{B}$)

$\vec{F} = q(\vec{V} \times \vec{B})$

The amount of deviation of particles from their path in the presence of electrical or magnetic field depends on...

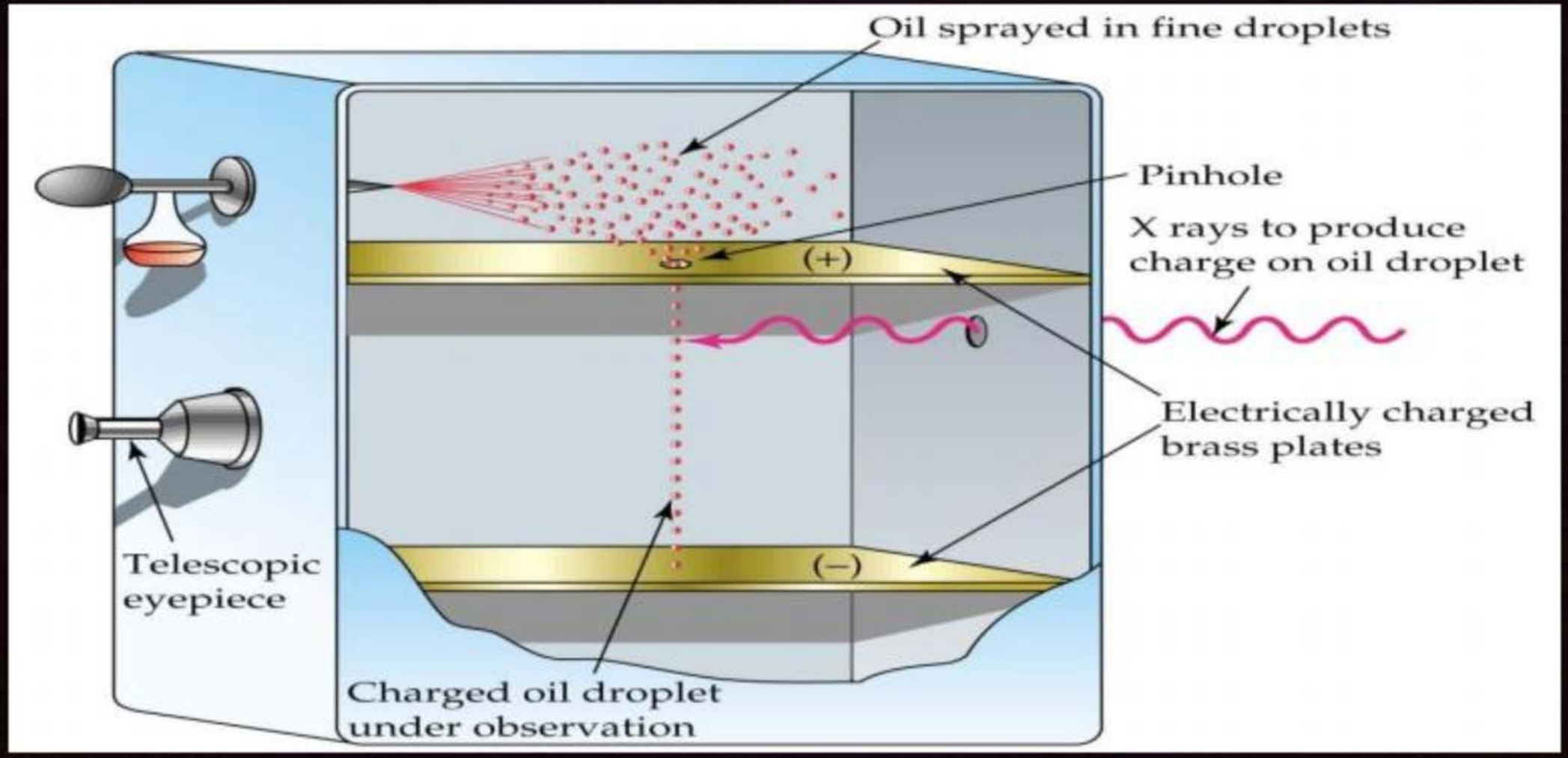
1. Greater the negative charge, greater is the interaction with electric or magnetic field. Thus, greater is the deflection.
2. Lighter the particle, higher is the deflection.
3. The deflection of electrons from their original path increases with increase in voltage across the electrode or the strength of electric field or magnetic field.

deviation of cathode rays $\propto$ charge $\propto$ electric and magnetic field $\propto \frac{1}{\text{mass}}$

$\frac{e}{m}$ = specific charge for electron $= 1.758 \times 10^{11}$ C/kg

Charge on the Electron

→ Millikan's oil drop experiment



↑ air drag

↓ charged oil drop

gravitational + electrostatic

By carefully measuring the effect of electric field strength on the motion of oil droplets, Millikan concluded that the magnitude of electrical charge 'q' on the droplets is always an integral multiple of the electrical charge 'e'.

(i.e., q = ne, n = 1,2,3...) where $e = \pm 1.6 \times 10^{-19}$ Coulomb

In the chamber, the forces acting on the oil droplet are:

(1) Gravitational ↓

(2) Electrostatic ↓

(3) Drag force ↑

$Q = \pm ne$

$n = 1, 2, 3 - - -$

$$\left(\frac{e}{m}\right)_{electron} = 1.758 \times 10^{11}\ C/kg$$

$$e^{\ominus} = -1.6 \times 10^{-19}\ C$$

$$\text{mass of electron} = 9.1 \times 10^{-31}\ kg$$

$$Q = \pm ne$$

QUESTION

For $^{19}F^{-1}$, $^{16}O^{-2}$ ^{20}Ne, choose the correct statement.

9 8 10

(A) Both O^{-2} and F^- are isoelectronic

(B) All the given species have equal number of e^-

(C) F^- and Ne have equal number of e^-

(D) All of the above

QUESTION

Mass number of an atom (A) is equal to

A. total number of nucleons

B. total number of neutrons

C. total number of protons and electrons

D. total number of protons, electrons and neutrons

QUESTION

Which of the following substances, shows the properties of phosphorescent?

A Zinc sulphide

B Zinc sulphate

C Zinc nitrate

D Zinc chloride

QUESTION

Which of the following statement is not correct regarding cathode rays?

A Cathode rays originate from the cathode.

B Charge and mass of the particles constituting cathode rays depends up on the nature of the gas.

C Charge and mass of the particles constituting cathode rays does not depends up on the material of the cathode.

D They possess kinetic energy.

QUESTION

According to Thomson, the amount of deviation of the particles from their path in the presence of electrical or magnetic field depends upon

A the magnitude of the negative charge on the particle

B the mass of the particle

C the strength of the electrical or magnetic field

D All of the above

QUESTION

The e/m ratio of cathode rays is x unit, when hydrogen is filled in the discharge tube. What will be its value when deuterium (D_2) is filled in it?

A) x unit

B) 2x unit

C) x/2 unit

D) x/4 unit

QUESTION

The charge to mass ratio of electron was found to be:

A 1.6022×10^{-19} C kg^{-1}

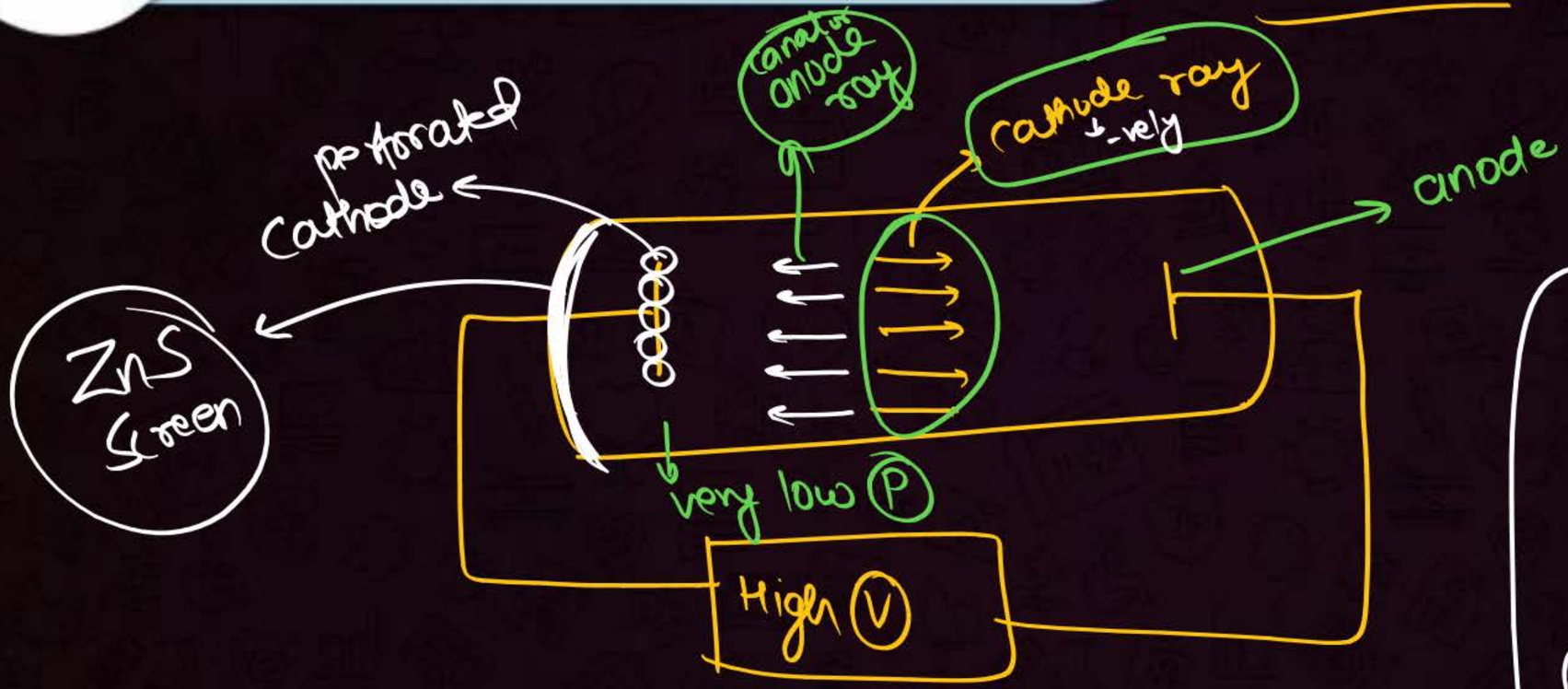
B 1.925×10^{12} C kg^{-1}

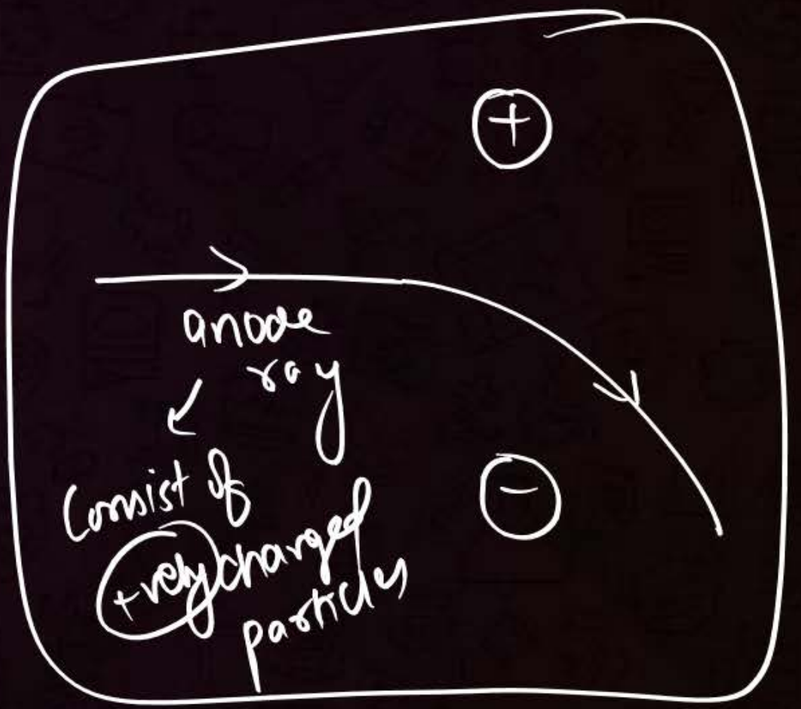
C 1.758×10^{11} C kg^{-1}

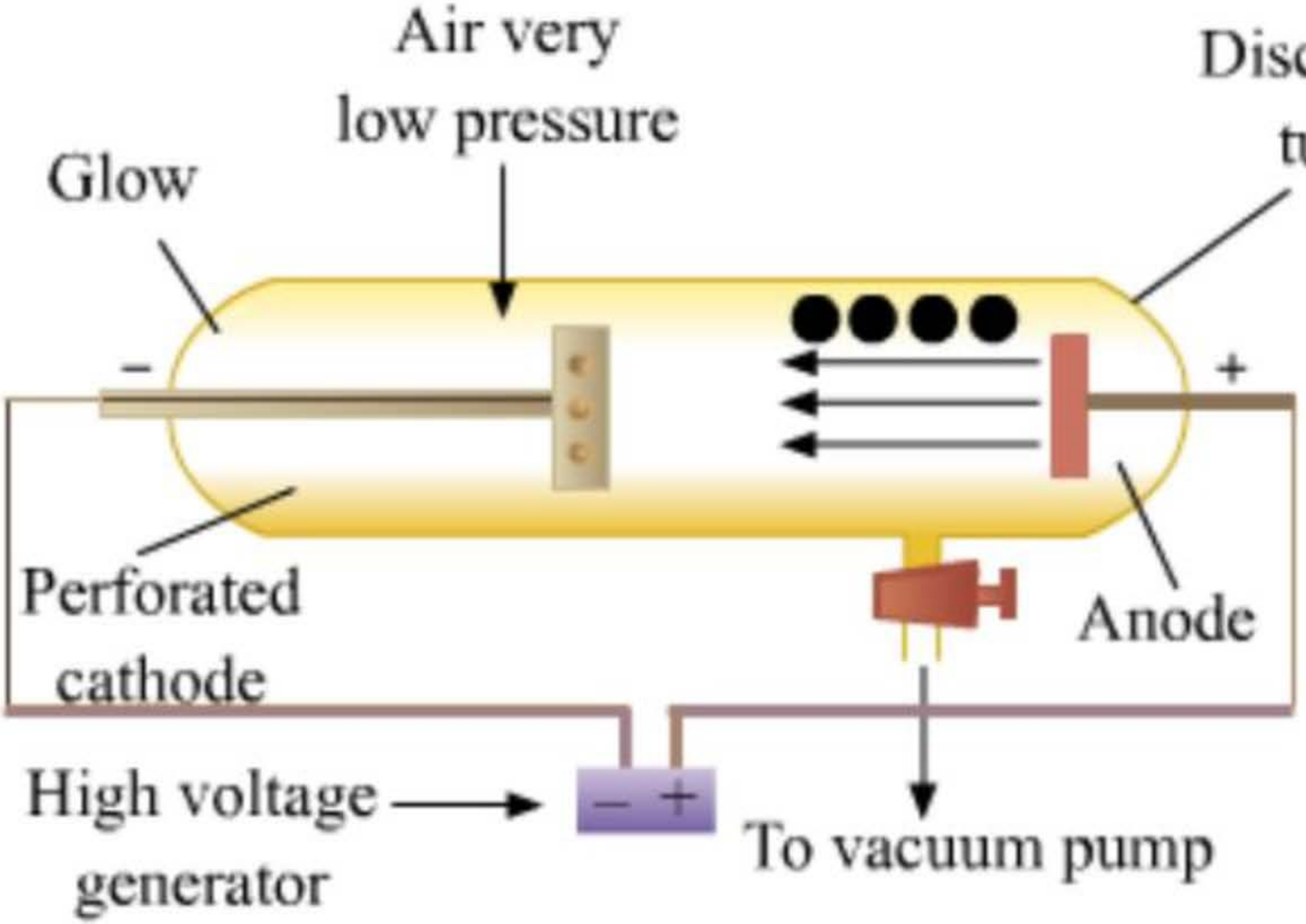
D 1.869×10^{13} C kg^{-1}

Discovery of Nucleons

- protons
- neutrons



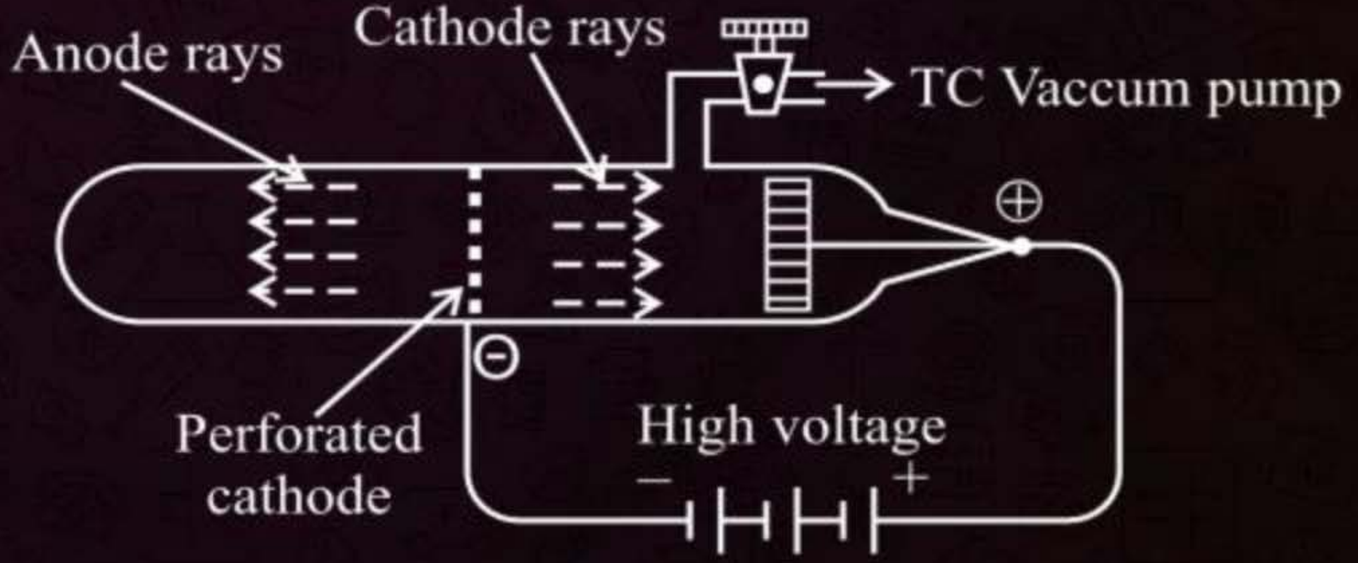




Production of anode rays

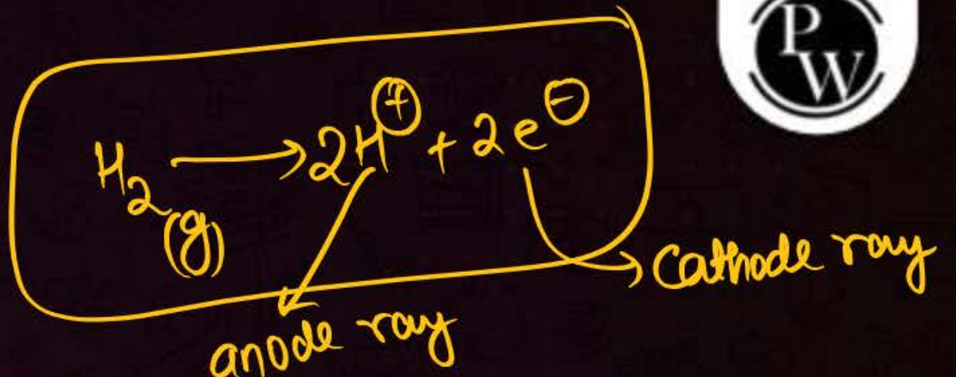
Discovery of Protons - Anode Rays

1. Proton was discovered by Goldstein and is positively charged particle. It is a component particle of anode rays.
2. **Goldstein (1886)** used perforated cathode in the discharge tube and repeated Thomson's experiment and observed the formation of anode rays. These rays also termed as positive or canal rays.



Perforated tube experiment for production of anode rays

Properties of Anode Rays



- Anode rays travel in straight lines.
- Anode rays consist of material particles.
- Anode rays are deflected by electric field towards negatively charged plate. This indicates that they are positively charged.
- When a magnetic field is applied, anode rays get deflected in the direction expected for positive particles. it indicates that they are positively charged.
- Charge to mass ratio of the particles in the anode rays depends upon nature of the gas taken in the discharge tube.
- e/m ratio is maximum when hydrogen gas is taken in the discharge tube. This indicate that positive ions formed from hydrogen are lightest.
- These lightest positively charged particles were named protons.

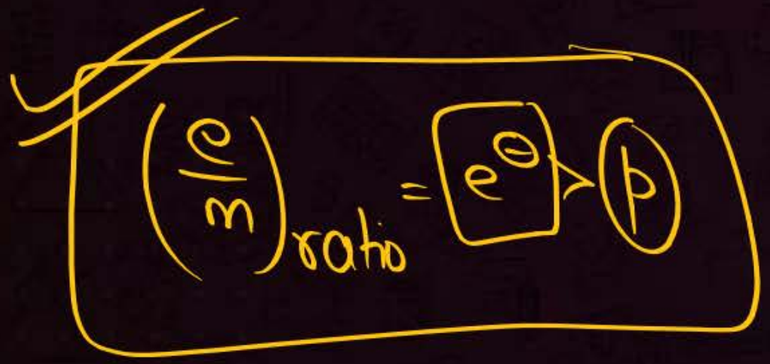
- The smallest and lightest positive ion obtained from hydrogen gas is called 'proton'.
- It is found that the mass of proton 1.672×10^{-24}g and charge is 1.6022×10^{-19}C.

e/m value of proton

$= 1.6022 \times 10^{-19}\ C / 1.672 \times 10^{-24}\ g$

$= 9.58 \times 10^{4}\ C/g$

$= 9.58 \times 10^{7}\ C/kg$



QUESTION

The e/m ratio of anode rays produced in the discharge tube, depends on the?

A Nature of the gas filled in the tube

B Nature of anode material

C Nature of cathode material

D All of these

QUESTION

Positive rays or canal rays are:

A Electromagnetic waves

B A stream of positively charged gaseous ions

C A stream of electrons

D Neutrons

QUESTION

Statement-I: The charge to mass ratio of the particles in anode rays depends on nature of the gas taken in the discharge tube.

Statement-II: The particles in anode rays carry positive charge.

(A) Both Statement-I and Statement-II are correct.

(B) Both Statement-I and Statement-II are incorrect

(C) Statement-I is correct and Statement-II is incorrect

(D) Statement-I is incorrect and Statement-II is correct

Discovery of Neutron

α-particle = nucleus of He^{+2}

$^{4}_{2}He$: p = 2, n = 2, e = 2

$^{4}_{2}He^{+2}$: p = 2, n = 2, e = 0

- Neutron was discovered by James Chadwick.
- These particles were discovered by bombarding a thin sheet of Beryllium (Be) by an alpha (α) particle.

α particle is doubly ionized Helium ion (He^{2+})

nuclear rxn

$$^{9}_{4}Be + {}^{4}_{2}He^{2+} \rightarrow {}^{12}_{6}C + {}^{1}_{0}n \text{ (neutron)}$$

$$^{27}_{13}Al + {}^{4}_{2}He^{2+} \rightarrow {}^{30}_{15}P + {}^{1}_{0}n \text{ (neutron)}$$

$$\left(\frac{e}{m}\right)_{\alpha\text{-particle}} = \frac{2 \times 1.6 \times 10^{-19}}{4 \times m_p} = \frac{1}{2}\left(\frac{e}{m_p}\right)$$

$$\left(\frac{e}{m}\right)_{\alpha} = \frac{1}{2}\left(\frac{e}{m}\right)_{\text{proton}}$$

- Neutrons were not deflected by both magnetic and electric fields indicatingthat they are neutral particles. (i.e., Charge less particles) (i.e., charge is zero)
- The mass of neutrons is found to be slightly higher than proton. It is found to be **1.675×10^{-24}g (or) 1.675×10^{-27} Kg**

$\left(\frac{e}{m}\right) \Rightarrow e > p > \alpha > n$

e/m value = $0/1.675 \times 10^{-24} = 0$

Rutherford obtained protons by bombarding nitrogen atomic nucleus with alpha - particle.

particles	Mass	Relative Mass	Charge	Relative charge	Specific charge
Electron	0.000546 amu 9.1094×10^{-31} kg	$\frac{1}{1837}$	-1.602×10^{-19} C	-1	1.76×10^{11} C/kg
Proton	1.00728 amu 1.673×10^{-27} kg	1	1.602×10^{-19} C	1	9.58×10^{7} C/kg
Neutron	1.008665 amu 1.675×10^{-27} kg	1	0	0	0

QUESTION

What are the essential conditions for the production of anode rays?

A. High voltage and low pressure

B. High voltage and high pressure

C. Low voltage and high pressure

D. Low voltage and low pressure

QUESTION

Which of the following is not true for cathode rays?

A Cathode rays consist of negatively charged particles.

B Cathode rays were discovered by J.J Thomson.

C Nature of cathode rays depend upon the nature of the gas in discharge tube.

D Cathode rays are produced inside the discharge tube.

QUESTION

Which is true?

(A) e/m values of cathode rays generated by discharge of different gases are different

(B) (e/m) value of anode rays generated by discharge of different gases is same

(C) $\left(\frac{e}{m}\right)_{proton} > \left(\frac{e}{m}\right)_{electron}$

(D) $\left(\frac{e}{m}\right)_{proton} > \left(\frac{e}{m}\right)_{\alpha-partide}$

QUESTION

Gases are bad conductors of electricity. Their conductivity may be increased by

A. Increasing the pressure as well as potential difference between the electrodes.

B. Decreasing the pressure as well as potential difference between the electrodes.

C. Decreasing the pressure and/or increasing the potential difference between the electrodes.

D. Increasing the pressure and/or decreasing the potential difference between the electrodes.

QUESTION

The specific charge of cathode rays

A. Depends on the nature of the gas.

B. Depends on the material of the discharge tube.

C. Depends on the potential difference between cathode and anode.

D. Is a universal constant

QUESTION

The ratio of mass of an electron to that of the mass of hydrogen atom is

A 1 : 3871

B 1 : 1837

C 1 : 1296

D 1 : 3781

$m_e : m_p$

QUESTION

Millikan's oil drop experiments is used to find

A e/m ratio of an electron

B Charge on an electron ✓

C Mass of an electron

D Velocity of an electron

QUESTION

α-particles are represented by

A Lithium atoms

B Helium nuclei

C Hydrogen nuclei

D None of these

QUESTION

The increasing order for the values of e/m (charge/mass) is:

A) e, p, n, α

B) n, p, e, α

C) n, p, α, e

D) n, α, p, e

QUESTION

The e/m ratio is maximum for

A Na^+

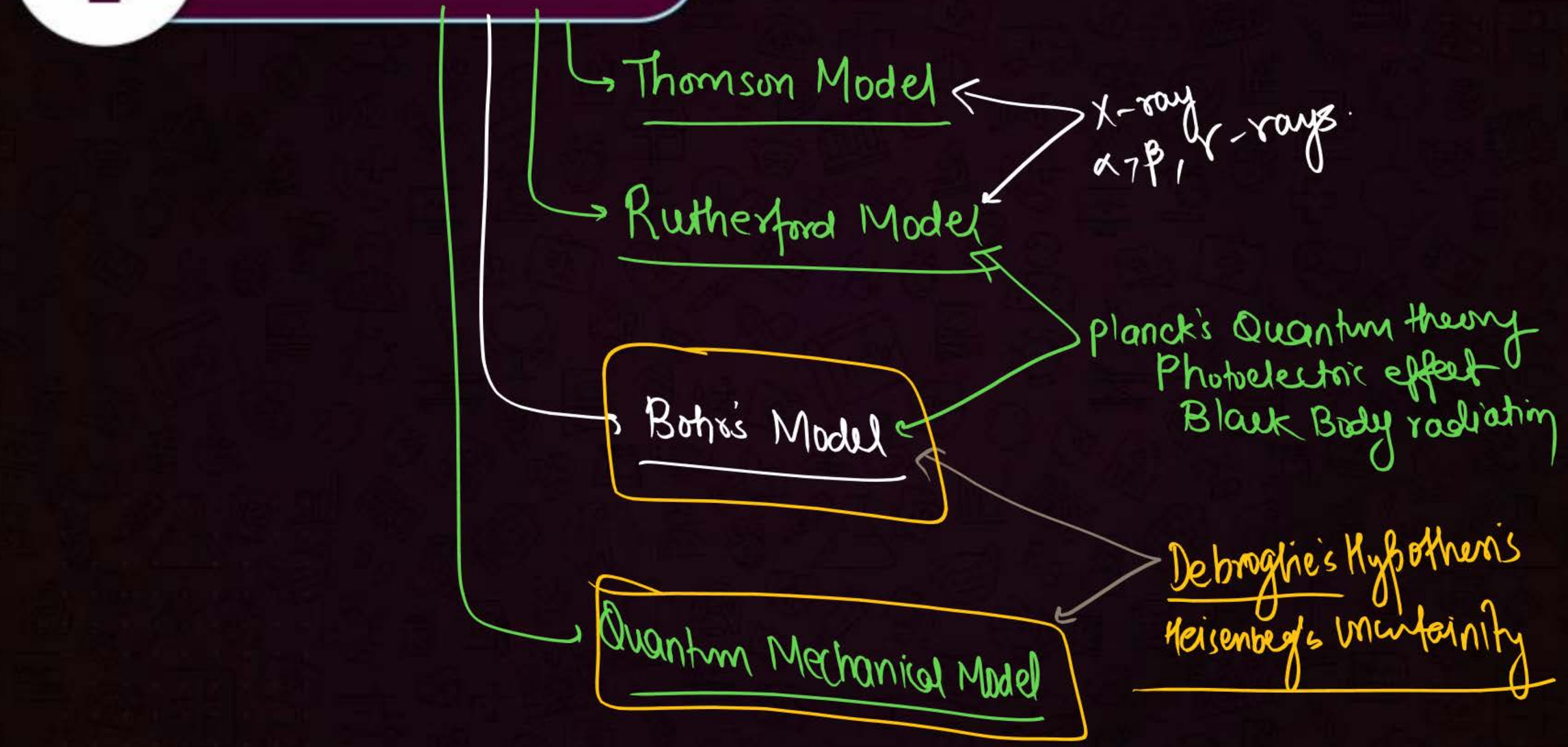
B Al^{3+}

C H^+

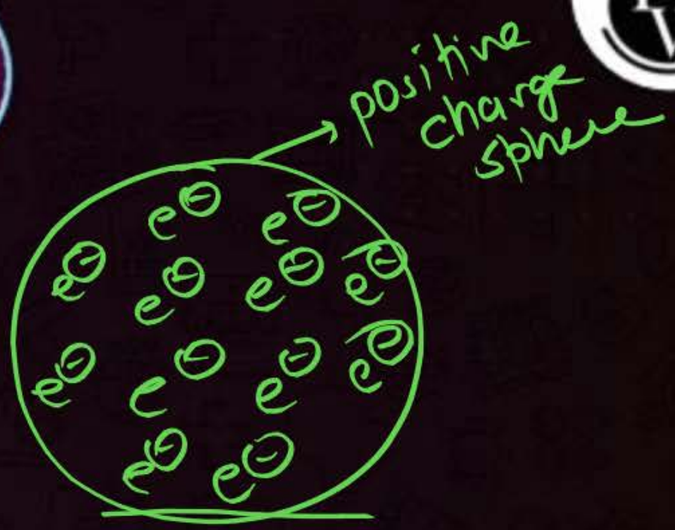
D Mg^{2+}



Atomic Models



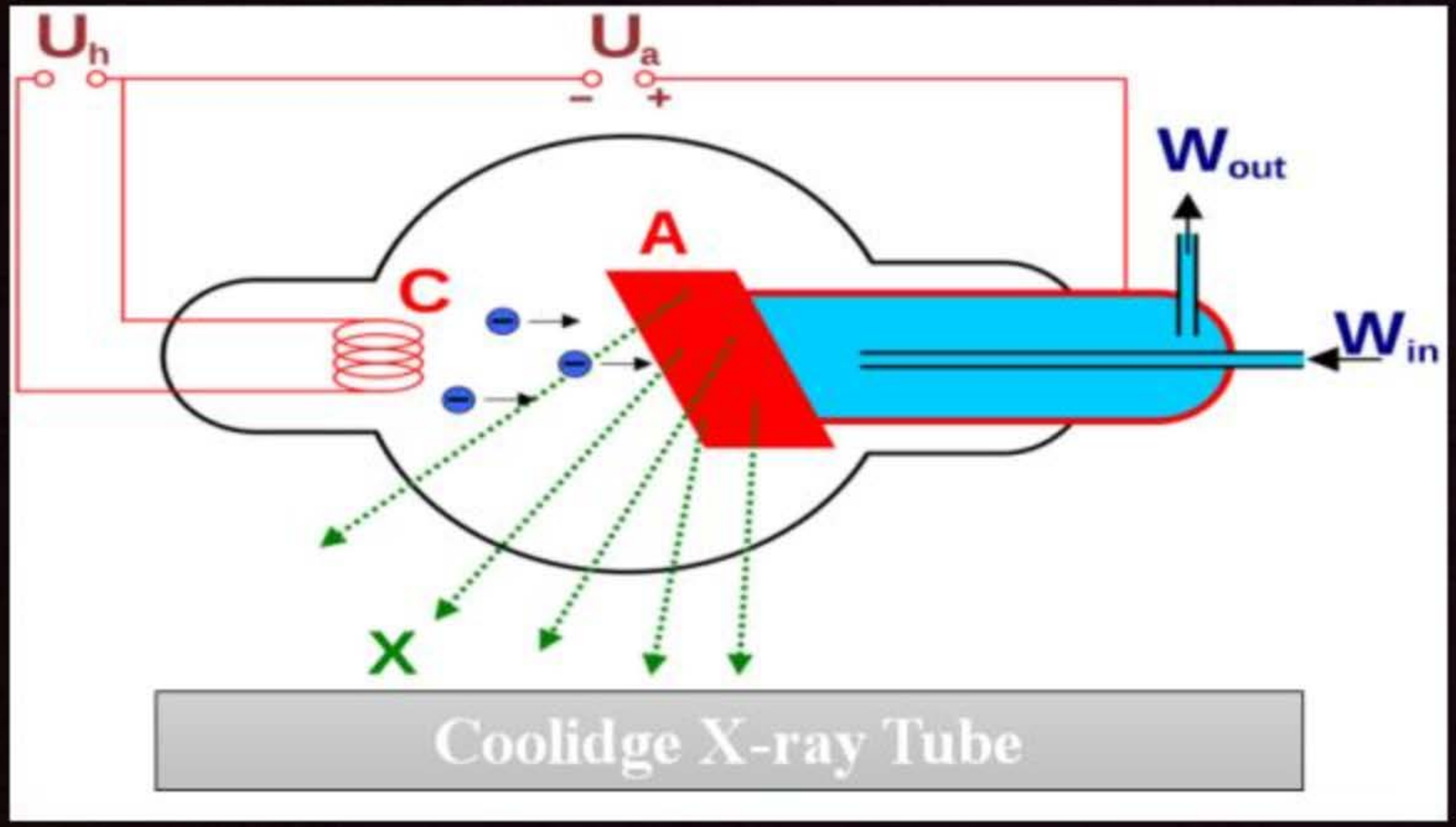
J.J Thomson Model of an Atom

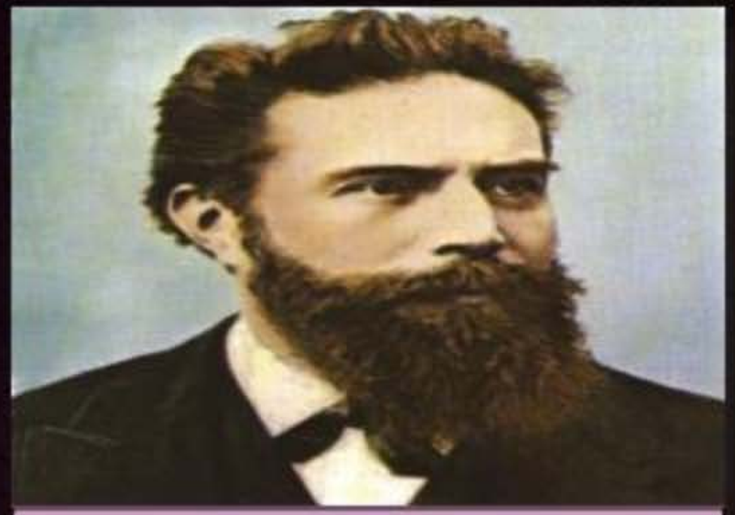


According to J.J Thomson,

- Atom is spherical in shape.
- Radius of an atom is approximately 10^{-10} m =1 A^0.
- Positive charge is uniformly distributed through out the sphere.
- Electrons are arranged in such a manner to give most stable electrostatic arrangement.
- The mass of the atom is assumed to be distributed uniformly through out the atom.

X-ray Discovery





Roentgen



Coolidge Type X-ray Tube

Roentgen discovered X-rays when cathode rays strike the target anode.

- Roentgen did not know the properties of these rays emitted from target anode and called them as x-rays.

- X-rays are powerful electromagnetic radiations with wavelength nearly 0.1 nm.

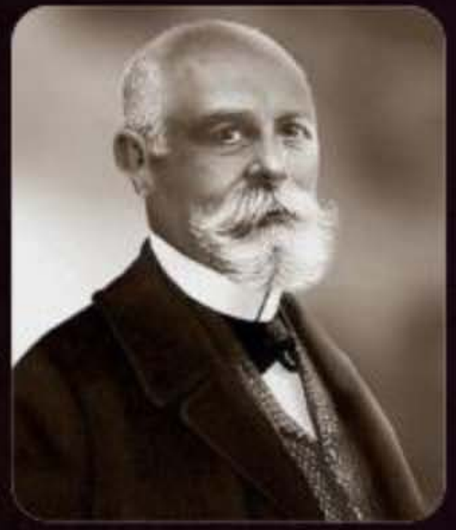


- X-rays have high penetrating power, hence are used for the study of interior structure of atom or matter.
- X-rays are not deflected by electric and magnetic fields.

→ part of electromagnetic spectrum

Radioactivity

The substances which show the property of radioactivity are called radioactive elements.



Henry Becquerel

e.g. U(uranium),
Th(thorium)
Ra(Radium),
Fr(Francium) etc.

α-rays → not part of electromagnetic spectrum.

- α-rays are doubly ionized helium nuclei
- α-rays are deflected by both electric and magnetic fields.
- α-rays are deflected towards negative plate.

β-ray → $^{0}_{-1}e$ } not the part of E.M. waves.

- β-rays are negatively charged and bend towards positive plate in electric field.
- β-rays travel with higher velocities compared to α-rays
- The penetration power of β-rays is 100 times more than α-rays.

γ-rays

- ϒ-rays are highly energetic radiations with much lower wavelengths than X-rays.
- ϒ-rays have highest penetration power than Alpha, Beta . Gamma rays are neutral and are a part of the electro-magnetic spectrum.
- Penetration power of alpha: beta : gamma rays = 1: 100: 1000
- Gamma rays are most harmful to biological species compared to alpha and beta rays due to highest penetration power and can cause mutation in biological species.
- α-rays, β-rays, and ϒ-rays effect photographic plate. But maximum effect is shown by beta rays due to their highest e/m ratio.

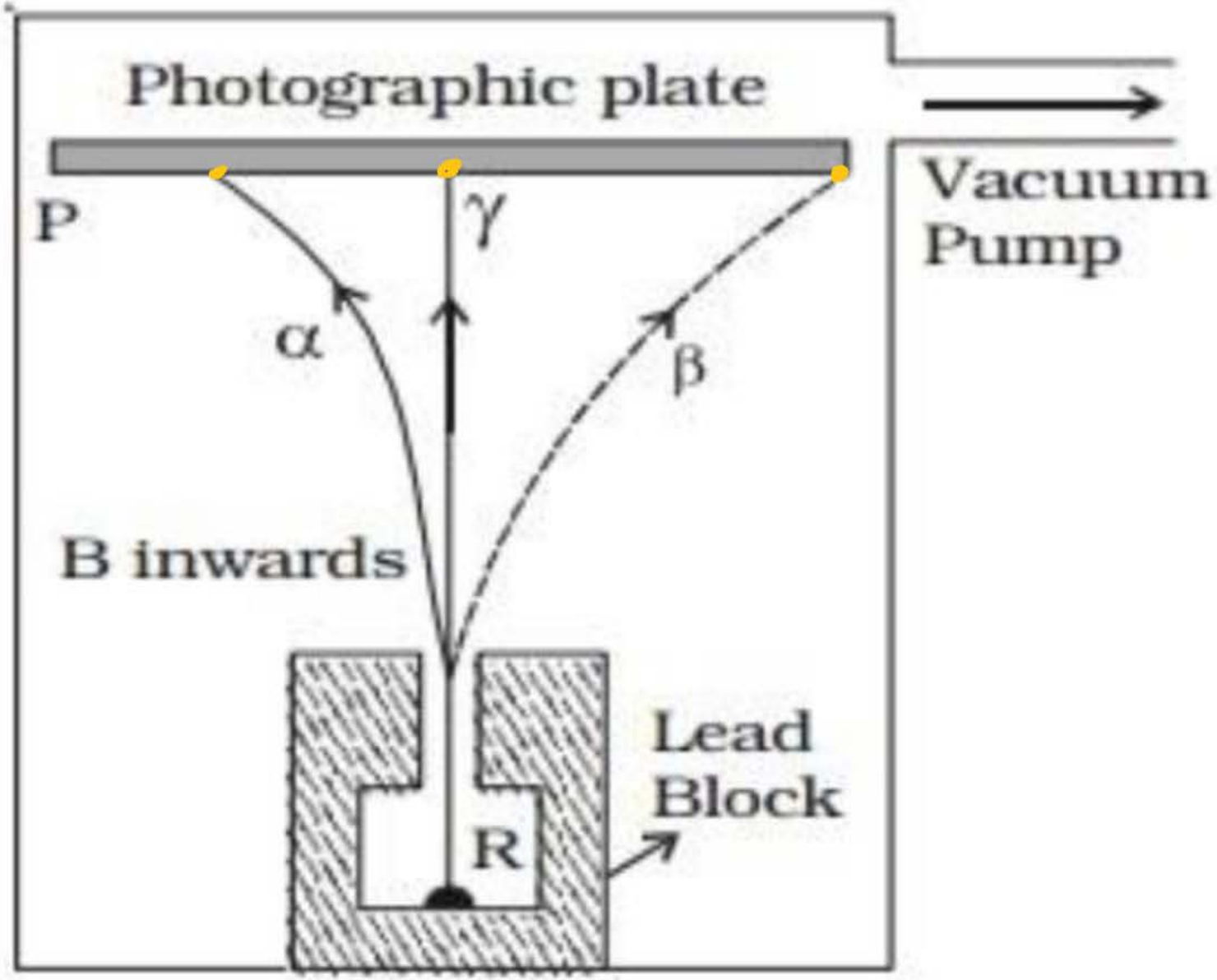


Fig Radioactivity

QUESTION

Cathode rays have same charge to mass ratio as

A. β-rays

B. α-rays

C. anode rays

D. None of the above

Charge on nucleus of any atom ⇒ $(+e) \times (Z) = +Ze$

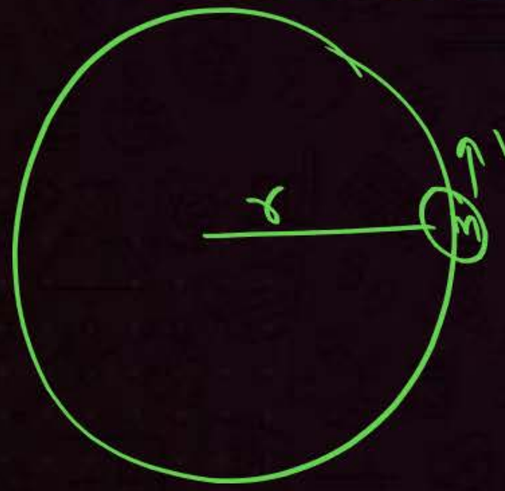
$(+e)$ → charge on 1 proton

Z → no. of protons

(p) momentum = mv

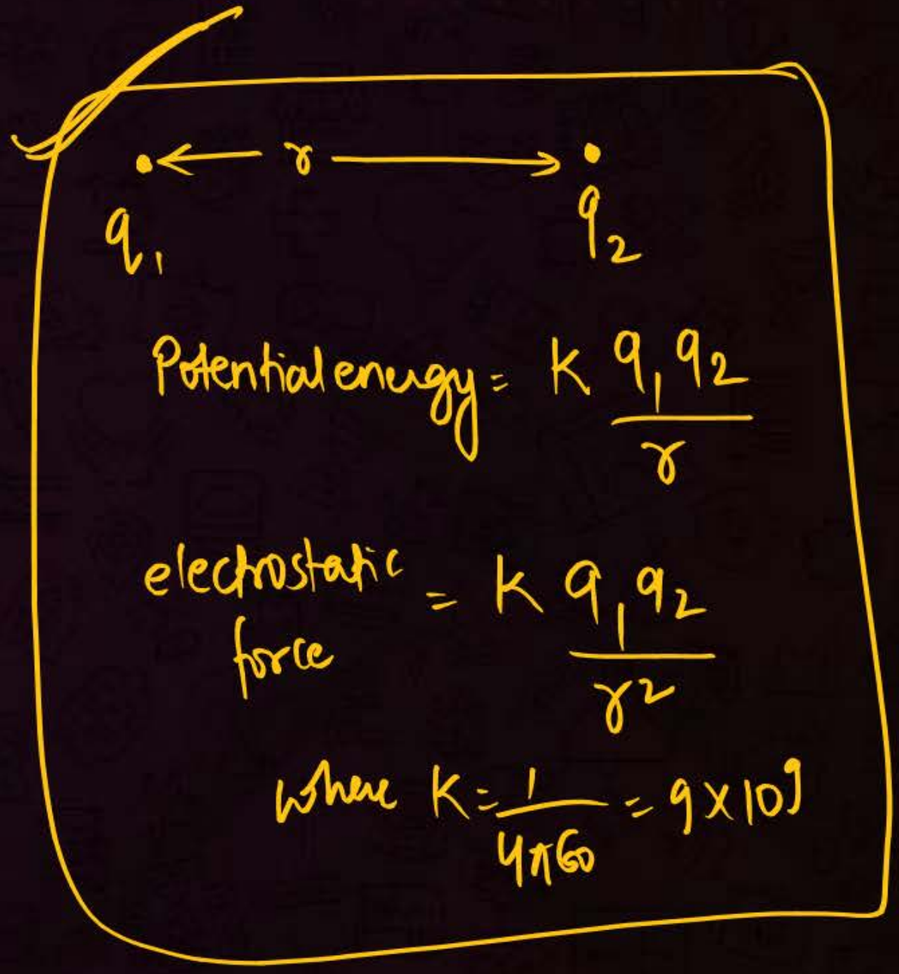
$m \rightarrow v$

Kinetic energy = $\frac{1}{2}mv^2$



angular momentum = mvr

Centrifugal / centripetal force = $\frac{mv^2}{r}$



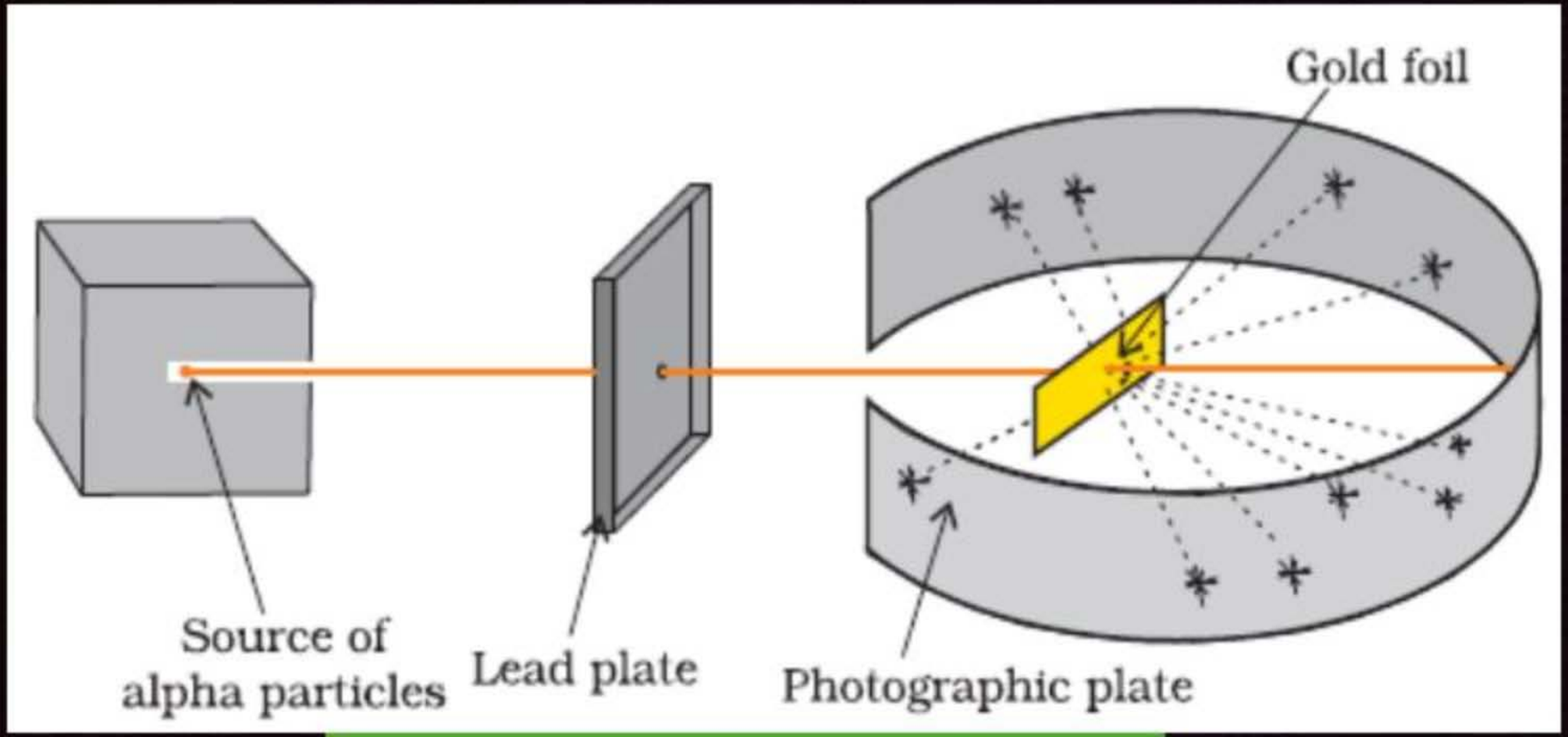
Potential energy = $K\frac{q_1 q_2}{r}$

electrostatic force = $K\frac{q_1 q_2}{r^2}$

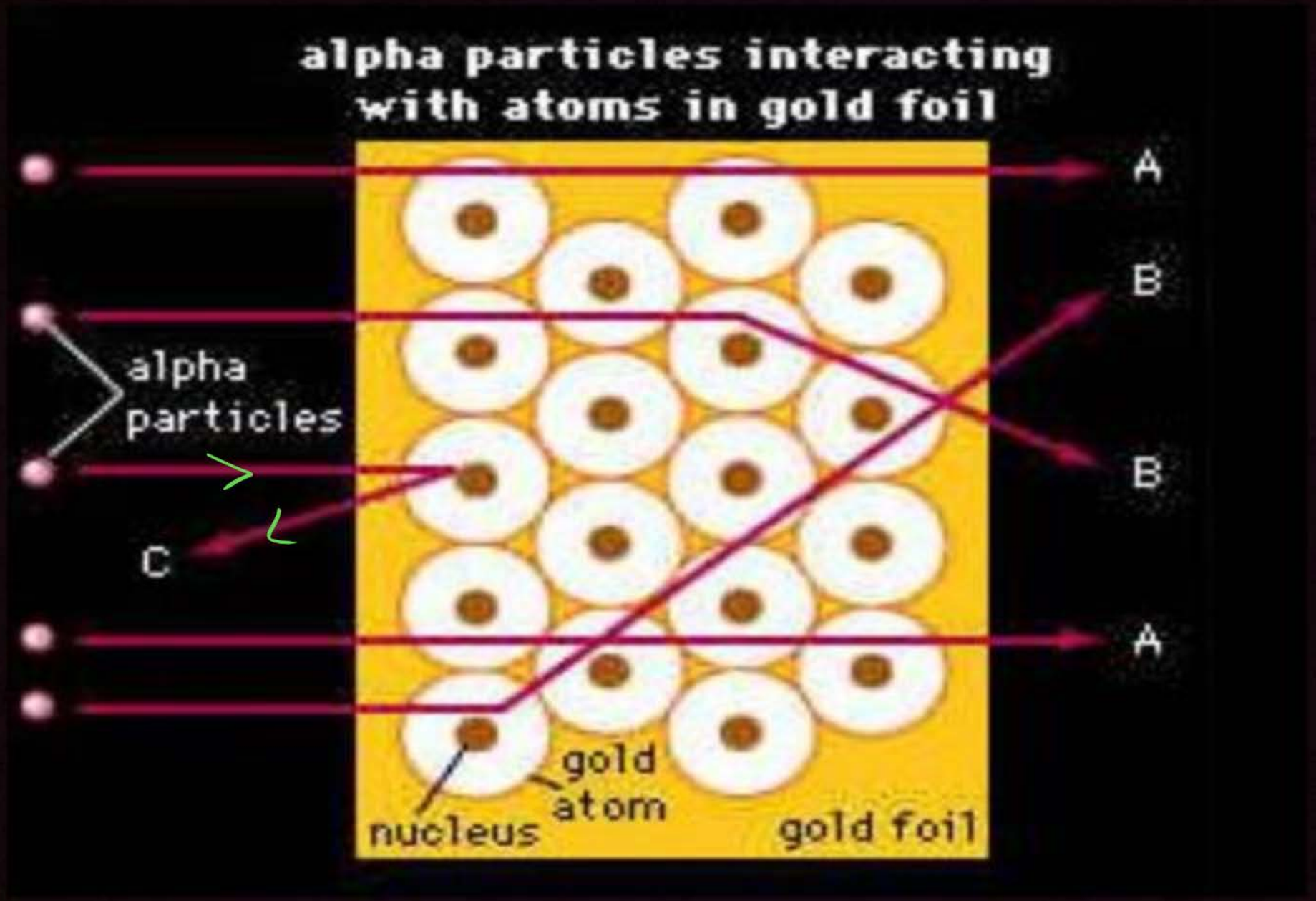
where $K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9$

Rutherford's Model of an Atom

- Rutherford bombarded a thin gold foil of thickness of about 100nm with alpha rays(particles).
- The thin gold foil has a circular fluorescent Zinc sulphide screen around it.
- Whenever alpha rays strike ZnS screen, they cause glow (flash of light)on the screen.



α- ray scattering experiment


alpha particles interacting with atoms in gold foil
A
B
B
A
alpha particles
C
gold atom
nucleus
gold foil

Observations of the Alpha Ray Scattering Experiment are

- Most of the α-particles passed through the gold foil undeflected.
- A small fraction of α particles was deflected by small angles.
- A very few α particles (1 in 20,000) retraced their path (i.e., bounced back)

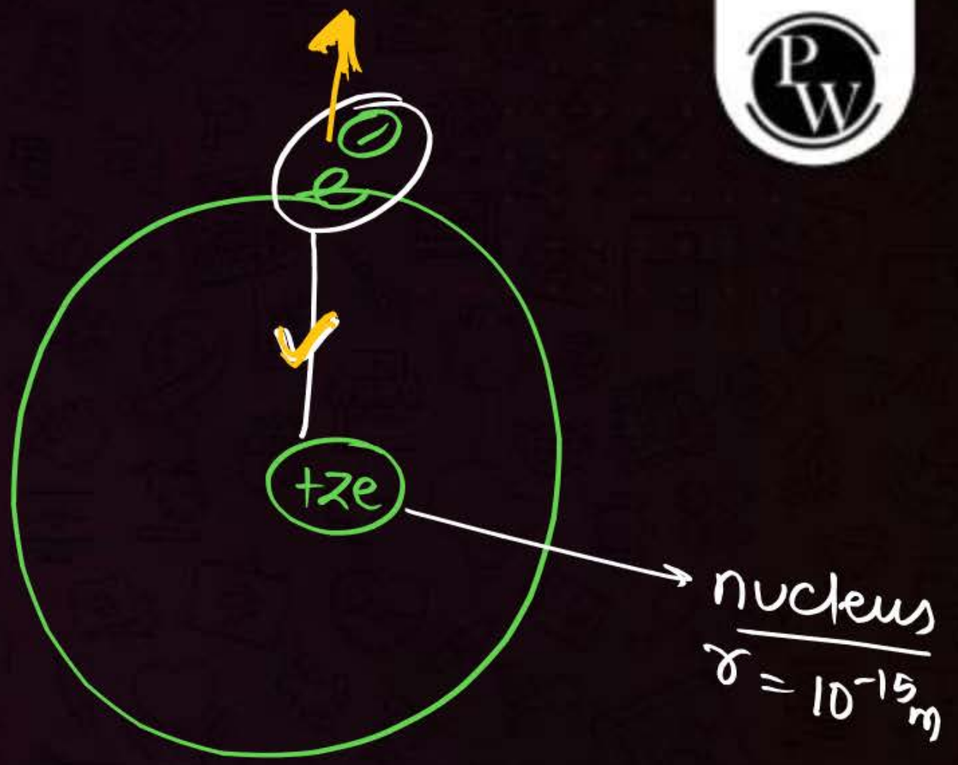
Conclusions

- Most of the space in the atom is empty as most of the alpha particles passed through the gold foil undeflected.
- A few alpha particles were deflected indicates that atom has high density of positive charge in small volume of the atom, which causes repulsion to the incoming alpha particles causing deflection from their path.
- The central part of the atom in which entire positive charge and mass is concentrated is called **nucleus.**
- The radius of the atom is about 10^{-10} m = 1.0 Å
- The radius of the nucleus is about 10^{-15} m.

Rutherford Model / Planetary Model

① electrostatic force b/w nucleus & $e^{\ominus}$ = Centrifugal force

$$\frac{K(+ze)(-e)}{r^2} = \frac{mv^2}{r}$$



② $r_{atom} = 10^{-10}\,m$, $r_{nucleus} = 10^{-15}\,m$

$$\frac{r_{atom}}{r_{nucleus}} = \frac{10^{-10}}{10^{-15}} = 10^5 = 100000$$

$r_{atm} = 1,00,000\ r_{nucleus}$

③ $$\frac{V_{atm}}{V_{nucleus}} = \frac{\frac{4}{3}\pi(r_{atm})^3}{\frac{4}{3}\pi(r_{nucleus})^3} = \left(\frac{r_{atm}}{r_{nucleus}}\right)^3 = (10^5)^3 = 10^{15}$$

$V_{atm} = 10^{15}\ V_{nucleus}$

Drawback of Rutherford Model

① Maxwell → charged particle, under accelerated motion, emits electromagnetic radiation and loses energy.

→ 10^{-8} sec → $e^{\ominus}$ plunges into nucleus.



② How $e^{\ominus}$ are arranged in an atom!

QUESTION

The fraction of volume occupied by the nucleus with respect to the total volume of an atom is

(A) 10^{-15}

(B) 10^{-5}

(C) 10^{-30}

(D) 10^{-10}

$$\frac{V_{nucleus}}{V_{atom}} = \frac{1}{10^{15}} = 10^{-15}$$

QUESTION

When a gold sheet is bombarded by a beam of α-particles, only a few of them get deflected whereas most go straight, undeflected. This is because

A. The force of attraction exerted on the α- particle by the oppositely charged electrons is not sufficient.

B. A nucleus has a much smaller volume than that of atom

C. The force of repulsion acting on the fast moving α-particles is very small.

D. The neutrons in the nucleus do not have any effect on the α-particles

QUESTION

Which of the following is not a conclusion of Rutherford's atomic model?

A. Most of the part inside an atom is empty.

B. Almost all mass of an atom is concentrated in the nucleus.

C. The size of nucleus is very small in comparison to the size of atom.

D. Electron revolves around the nucleus in definite orbits.

QUESTION

The radius of nucleus is approximately ___times smaller than the radius of atom.

A 1,00,000

B 5,000

C 10,000

D 200

QUESTION

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.

(B) γ-rays, which impinged on a metal foil and ejected electrons.

(C) helium atoms, which impinged on a metal foil and got scattered.

(D) helium nuclei, which impinged on a metal foil and got scattered.

Radius of Nucleus

Radius of nucleus $\propto$ (Mass number)$^{1/3}$

$$r_{nucleus} = r_0 (A)^{1/3}$$

where $r_0 = 1.33 \times 10^{-15}\ m = 1.33$ fermi

$^{8}_{3}X$ → $r_{nucleus} = r_0 \times (8)^{1/3} = 2r_0 = 2 \times 1.33 \times 10^{-15}\ m$

QUESTION

Radius of nucleus varies as $R = R_0 (A)^{1/3}$ where $R_0 = 1.3$ Fermi. What is the volume of Be^8 nucleus (approx.) [A = atomic mass]?

$r_{nucleus} = 2r_0 = 2 \times 1.3 \times 10^{-15}$ m

$= 2 \times 1.3 \times 10^{-13}$ cm

(A) 7×10^{-38} cc

(B) 7×10^{-29} cc

(C) 7×10^{-45} cc

(D) None of these

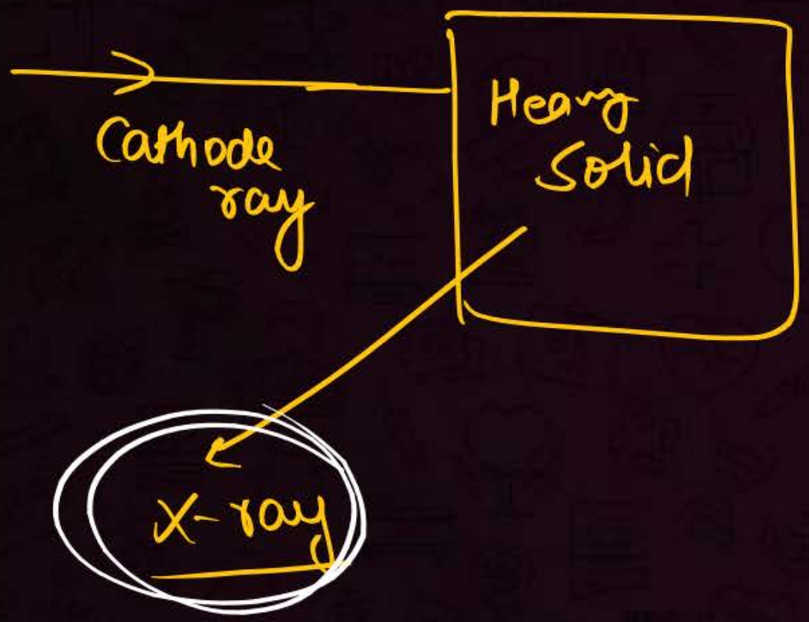
$V_{nucleus} = \frac{4}{3}\pi (r_{nucleus})^3 = \frac{4}{3} \times \pi \times (2.6 \times 10^{-13})^3$

$= \frac{4}{3}\pi \times (2.6)^3 \times 10^{-39}$ cm3

$= 73.66 \times 10^{-39}$ c.c

$\approx 7.36 \times 10^{-38}$

Mosley's experiment



frequency of x-ray (υ)

↳ depends on atomic no. (Z)

$\sqrt{\upsilon} \propto Z$

$\sqrt{\upsilon} = a(Z-b)$

where (a) & (b) are constants

$\upsilon \propto Z^2$

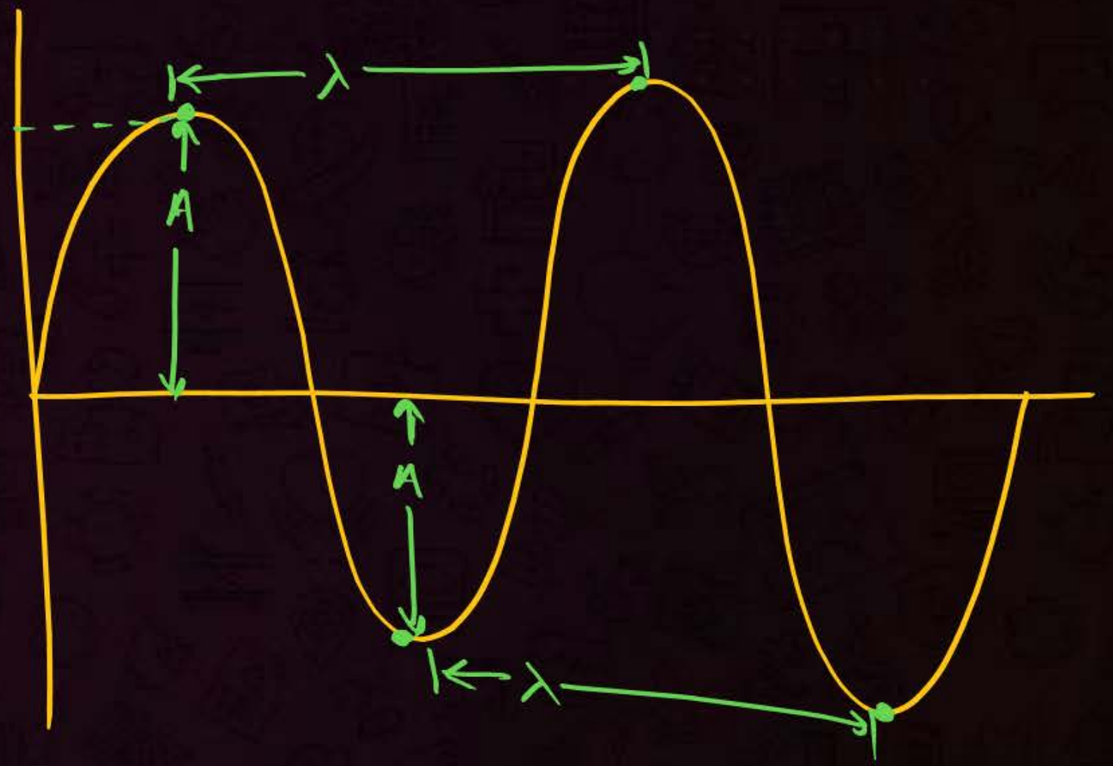
Waves

λ → wavelength

→ unit = unit of length.

→ popular unit ⇒ (nm), (A^0)

$1\ nm = 10^{-9}\ m$ $\quad 1A^0 = 10^{-10}\ m = 10^{-8}\ cm$.



frequency (υ) = no. of waves/cycles per unit second.

→ unit = Hertz or cycle per second (sec^{-1}) (cps)

Velocity of wave = frequency × wavelength

unit: m/s

$V = \upsilon \lambda$

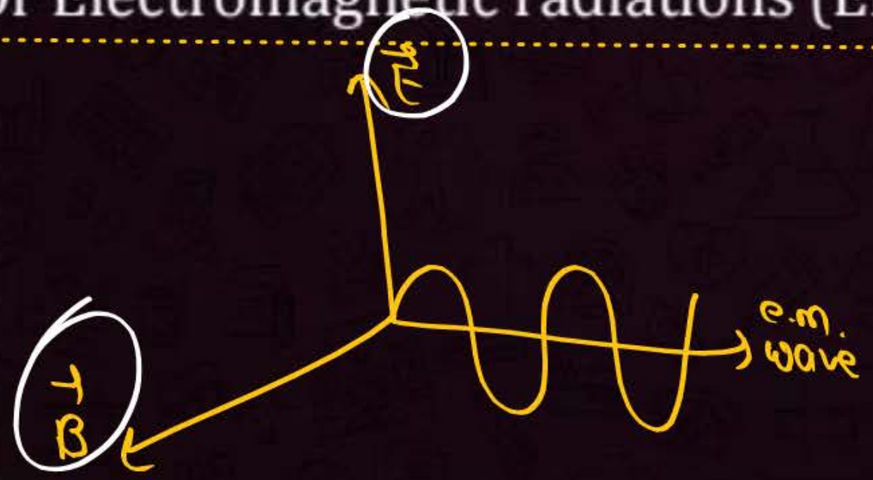
$\frac{1}{\upsilon}$ = Time period (T) = time to complete a wave/cycle.

$\frac{1}{\lambda}$ = $\bar{\upsilon}$ (wavenumber) = no. of waves per unit length.

Circumference = $2\pi r$

Wave Nature of Electromagnetic Radiation

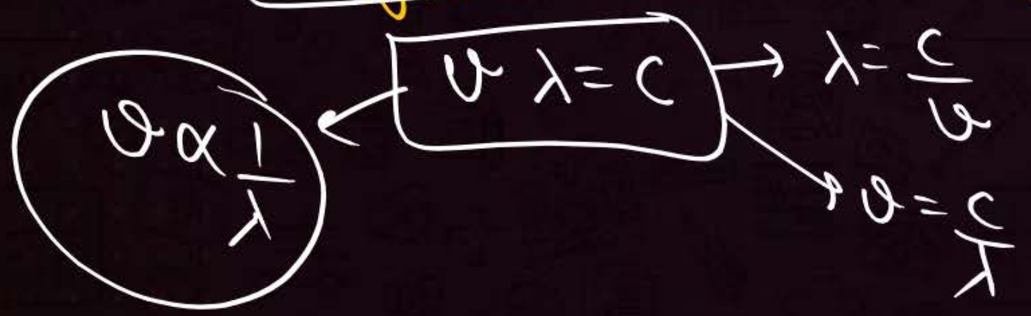
- James Maxwell suggested that when electrically charged particle moves under acceleration, alternating electric and magnetic fields are produced and transmitted.
- These fields are transmitted in the form of waves called electromagnetic waves (EMW) Or Electromagnetic radiations (EMR).

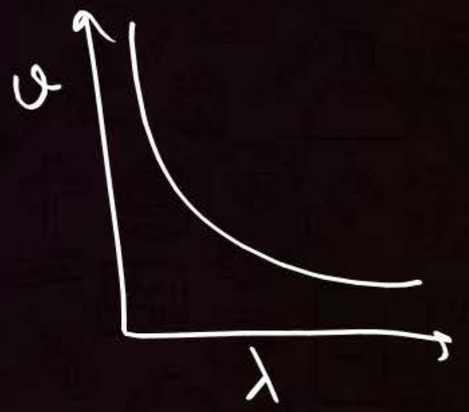


Electromagnetic Waves

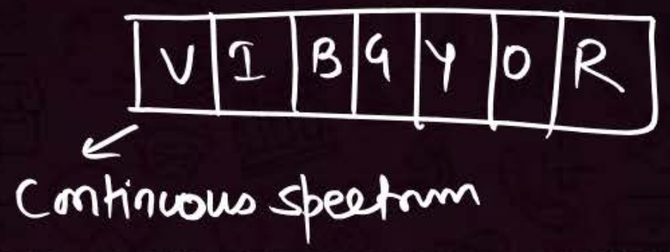
- The radiant energy is transmitted from one body to another in the form of waves.
- These waves travel in the space with the same speed as light (3×10^8 m/s).
- Do not need any medium for propogation.
- Have electric and magnetic fields and travel at right angle to these fields.

Velocity of e.m. wave = Speed of light (c) = 3×10^8 m/s

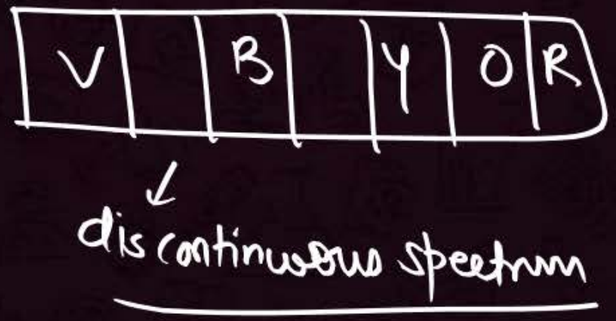




- A series of wavelengths of various colour bands of visible region is called spectrum.



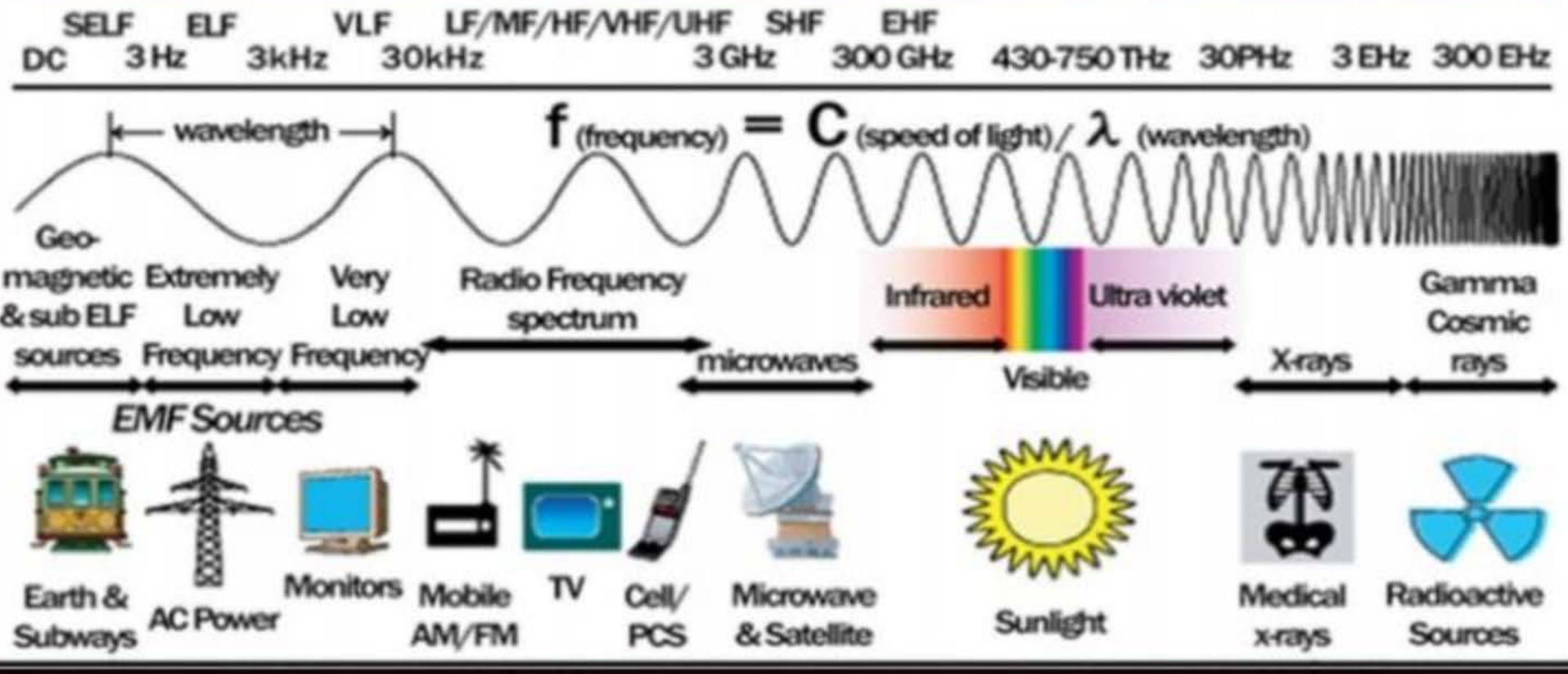
- A spectrum of electromagnetic radiation says visible light (or in fact of any region) without any gaps in its colour from violet to red is called *continuous spectrum.*



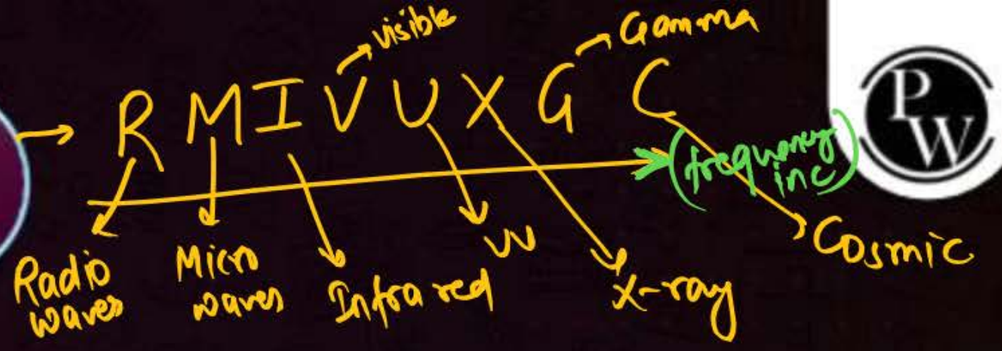
- If any wavelength or colour is missing from it, is called *discontinuous spectrum.*

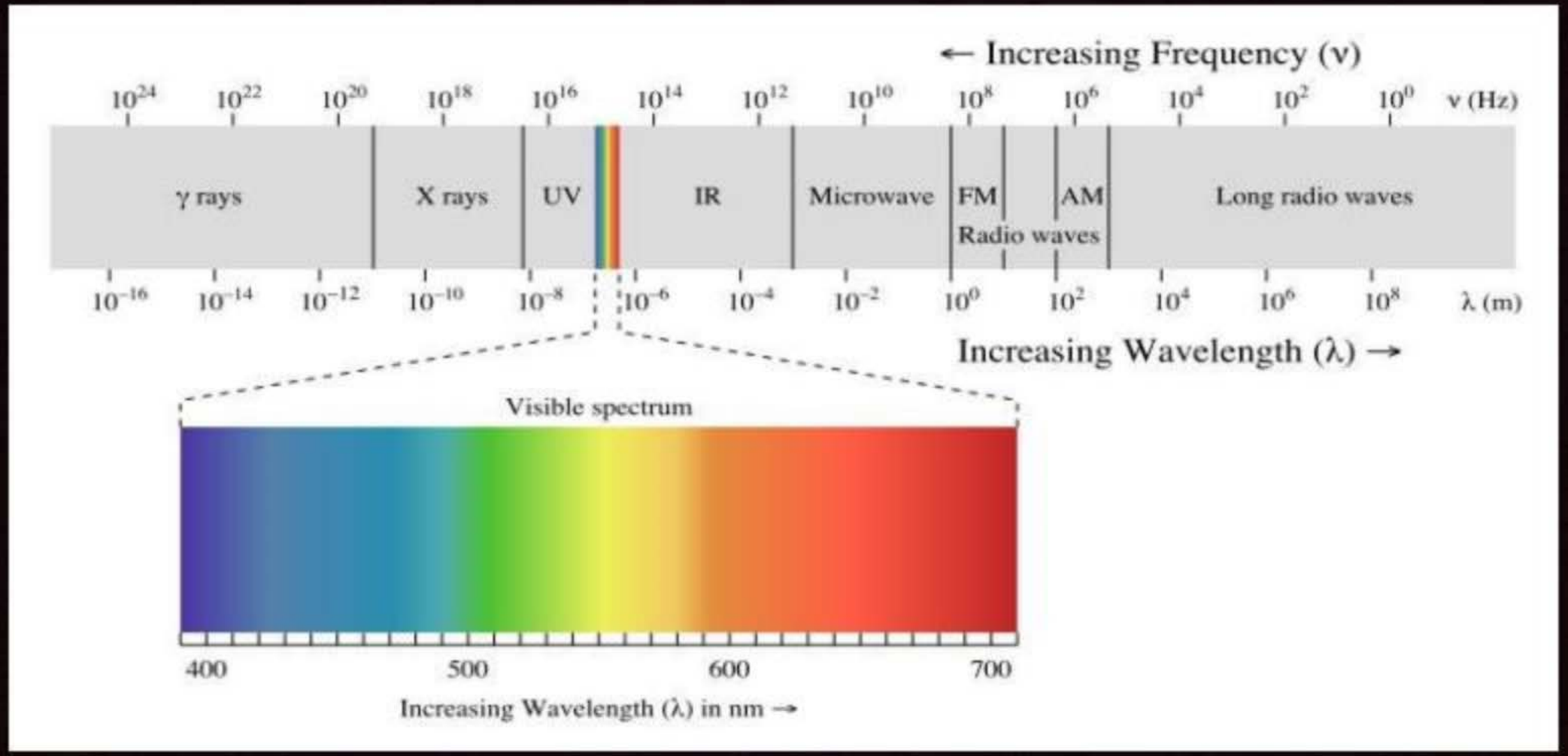
THE ELECTROMAGNETIC SPECTRUM

We are surrounded by electromagnetic radiation (EMR) like never before.
Studies link EMR to Cancer, Alzheimer's, Autism, chronic fatigue, headaches and other health issues.



Electromagnetic Spectra





QUESTION

Which of the following have maximum frequency?

λ inc.

R M I V U X G C

freq. inc

(A) Cosmic rays

(B) γ – rays

(C) Micro waves

(D) Radio waves

QUESTION

The correct order of increasing frequency of electromagnetic radiations is:

(A) Microwave < UV < IR < γ-rays

RMIVUXGC →

(B) Microwave < Radiowave < Visible < X-rays

(C) UV < Radiowave < X-rays < γ-rays

(D) Radiowave < IR < Visible < X-rays

QUESTION

AIR

A particular station of All India Radio, New Delhi, broadcasts on a frequency of 1,368 kHz (kilohertz). The wavelength of the electronmagnetic radiation emitted by the transmitter is: [speed of light, $c = 3.0 \times 10^8\ ms^{-1}$]

(A) 219.3 m

(B) 219.2 m

(C) 2192 m

(D) 21.92 cm

$\upsilon = 1368\ KHz = 1368 \times 10^3\ Hz.$

$\lambda = \frac{c}{\upsilon} = \frac{3 \times 10^8}{1368 \times 10^3} = \frac{300000}{1368}$

$\lambda = 219.3\ m$

QUESTION

Which of the following electromagnetic radiation have greater frequency?

A. X-rays

B. Ultraviolet rays

C. Radio waves

D. Visible rays

RMIVUXGC →

QUESTION

Which of the following statement is/are correct about Hertz (Hz)?

A. It is the SI unit of frequency (v)

B. It is named after Heinrich Hertz

C. It is the number of waves that pass a given point in one second

D. All of the above

QUESTION

According to the electromagnetic theory of Maxwell, which one is correct?

A. Charged particles when accelerated should emit electromagnetic radiation

B. Charged particles when accelerated should absorb electromagnetic radiation

C. Charged particles when retarted should emit EMR

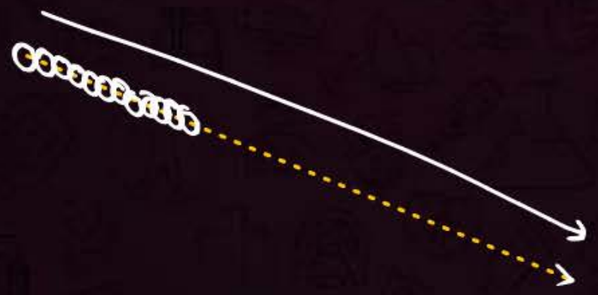
D. None of the above

Planck's Quantum Theory

(1) The radiant energy emitted or absorbed by a body is not continuous but discontinuous in the form of small discrete packets of energy and these packets are called quanta.

(2) In case of light, the smallest packet of energy is called as 'photon' but in general case the smallest packet of energy is called as quantum.

(3) The energy of each quantum is directly proportional to frequency of the radiation i.e.



Energy $\propto$ frequency (υ)

$E \propto \upsilon$

$\boxed{E = h\upsilon}$ where h = planck's constant

$h = 6.67 \times 10^{-34}$ J-s

for 1 photon

$$E = h\upsilon = \frac{hc}{\lambda} = hc\bar{\upsilon}$$

for n-photons

$$E = nh\upsilon = n\frac{hc}{\lambda} = nhc\bar{\upsilon}$$

Power = $\frac{\text{energy (J)}}{\text{time (s)}}$

↙

Unit = watt (W)

100 watt = $\frac{100\ \text{J}}{1\ \text{sec}}$

Intensity = $\frac{E}{At}$ — J

Area — sec

Units of energy

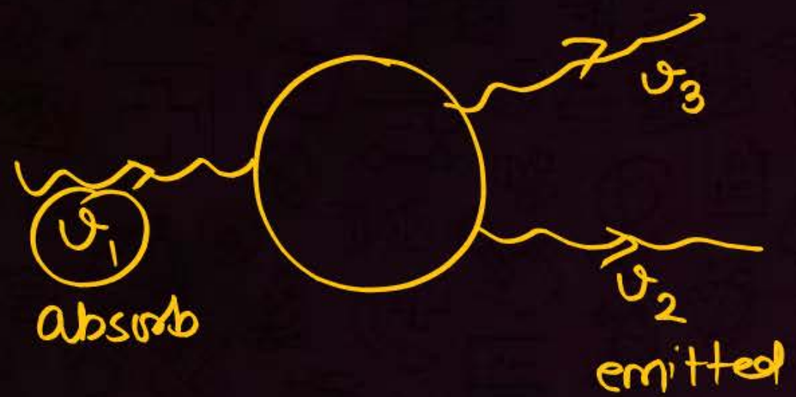
- 1 calorie = 4.2 J
- 1 electron-volt (eV) = 1.6×10^{-19} J

Shortcut

$$E_{(eV)} = \frac{1240}{\lambda(nm)} = \frac{12400}{\lambda(A^\circ)}$$

Intensity ↑ energy ↑ no. of photons ↑

Conservation of energy



Energy absorbed = Energy released.

$$h\upsilon_1 = h\upsilon_2 + h\upsilon_3$$

$$\boxed{\upsilon_1 = \upsilon_2 + \upsilon_3}$$

=



Energy absorbed = Energy released

$$\frac{hc}{\lambda_1} = \frac{hc}{\lambda_2} + \frac{hc}{\lambda_3}$$

$$\boxed{\frac{1}{\lambda_1} = \frac{1}{\lambda_2} + \frac{1}{\lambda_3}}$$

$$\boxed{\bar{\upsilon}_1 = \bar{\upsilon}_2 + \bar{\upsilon}_3}$$

$$\lambda_1 = \lambda_2 + \lambda_3$$

QUESTION

Calculate the Wavelength and frequency of a photon having an energy of 2 electron volt.

$E = h\upsilon = \frac{hc}{\lambda} = hc\bar{\upsilon}$

Sol:-

$E = 2eV = 2 \times 1.6 \times 10^{-19} J$

$E = h\upsilon$

$\upsilon = \frac{E}{h} = \frac{2 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = \frac{3.2}{6.6} \times 10^{+15} Hz = 0.48 \times 10^{15} Hz$

$= 4.8 \times 10^{14} Hz$

$\lambda = \frac{c}{\upsilon} = \frac{3 \times 10^{8}}{4.8 \times 10^{14}} = 0.625 \times 10^{-6}$

$= 625 \times 10^{-9} m$

$\Rightarrow 625 nm$

QUESTION

The energies E_1 and E_2 of two radiations are 25 eV, and 50eV, respectively. The relation between their wavelengths, i.e. λ_1 and λ_2 will be

A $\lambda_1 = \frac{1}{2}\lambda_2$

B $\lambda_1 = \lambda_2$

C $\lambda_1 = 2\lambda_2$

D $\lambda_1 = 4\lambda_2$

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

$$\frac{25}{\frac{50}{2}} = \frac{\lambda_2}{\lambda_1}$$

$$\lambda_1 = 2\lambda_2$$

QUESTION

Calculate the energy in joule corresponding to light of wavelength 45 nm (Planck's constant, $h = 6.63 \times 10^{-34}$ Js; speed of light, $c = 3 \times 10^{8}$ ms^{-1}).

A 6.67×10^{15}

B 6.67×10^{11}

C 4.42×10^{-15}

D 4.42×10^{18}

$E = \frac{1240}{45}$ eV $= 27.55$ eV

$\rightarrow 27.55 \times 1.6 \times 10^{-19}$ J

$\rightarrow 35.8 \times 10^{-19}$

$\Rightarrow 3.58 \times 10^{-18}$ J

QUESTION

$hc = 20 \times 10^{-26}$

The photons of light having a wavelength 4000 A° are necessary to provide 1.00 J of energy are

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

$$n = \frac{E\lambda}{hc} = \frac{1 \times 4000 \times 10^{-10}}{20 \times 10^{-26}}$$

$$\Rightarrow 2 \times 10^{+18}$$

(A) 6.023×10^{23}

(B) 6.023×10^{18}

(C) 2.01×10^{18}

(D) 2.01×10^{23}

QUESTION

The value of Planck's constant is 6.63×10^{-34} Js. The speed of light is 3×10^{17} nm s^{-1}. which value is closest to the wavelength in nanometer of a quantum of light with frequency of 6×10^{15} s^{-1}?

A 10

B 25

C 50

D 75

$\lambda = \frac{c}{\upsilon} = \frac{3 \times 10^8}{6 \times 10^{15}} = 0.5 \times 10^{-7}\ m$

$\rightarrow 50 \times 10^{-9}\ m$

$\rightarrow 50\ nm$

QUESTION

Number of photons emitted by a 100 W (Js^{-1}) yellow lamp in 1.0 s is (λ of yellow light is 560 nm)

A 1.6×10^{18}

B 1.4×10^{18}

C 2.8×10^{20}

D 2.1×10^{20}

100 W → 100 J/sec

$\lambda = 560\ nm \rightarrow 560 \times 10^{-9}\ m$

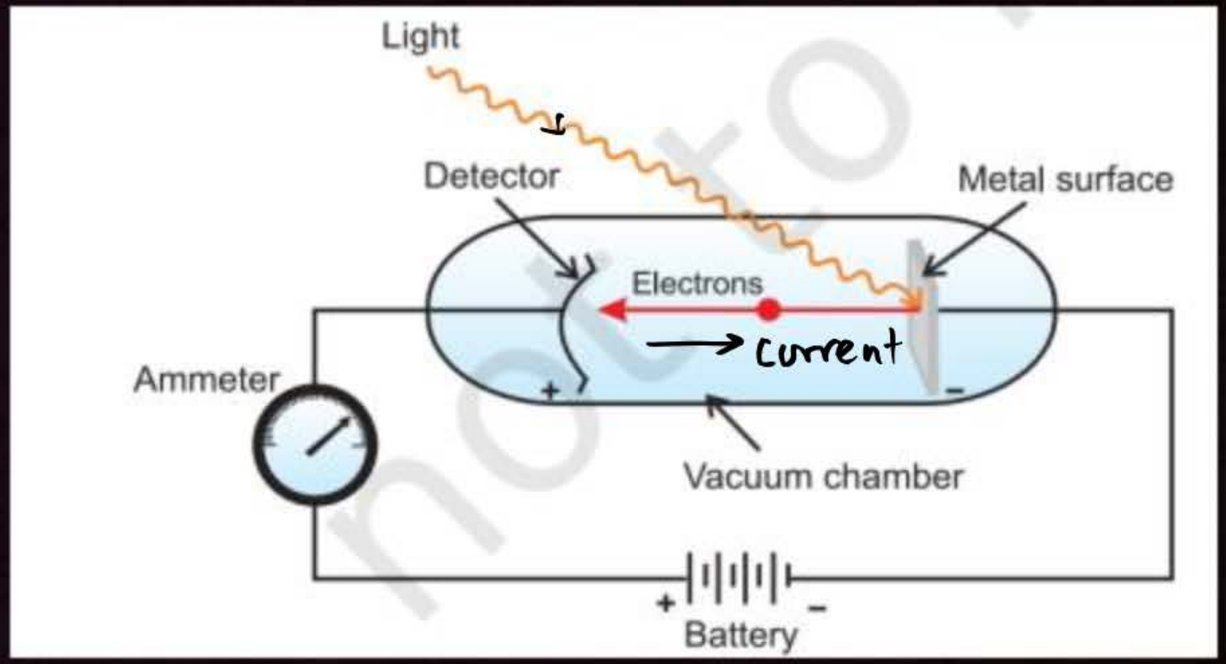
$E = \frac{nhc}{\lambda} \Rightarrow n = \frac{E\lambda}{hc} = \frac{100 \times 560 \times 10^{-9}}{20 \times 10^{-26}}$

$\Rightarrow 2800 \times 10^{+17}$

$\Rightarrow 2.8 \times 10^{20}$

Photoelectric Effect

In 1887, H. Hertz performed a very interesting experiment in which electrons (or electric current) were ejected when certain metals (for example potassium, rubidium, cesium etc.) were exposed to a beam of light. The phenomenon is called Photoelectric effect.



Threshold energy (E_0) / workfunction (ω)

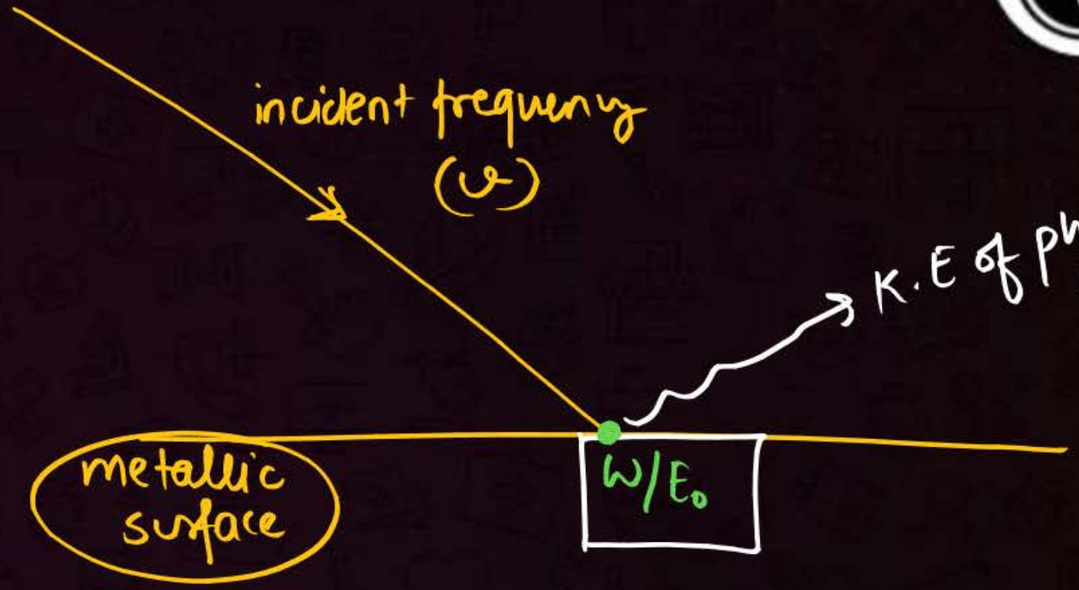
min energy required to eject $e^{\ominus}$ from metallic surface.

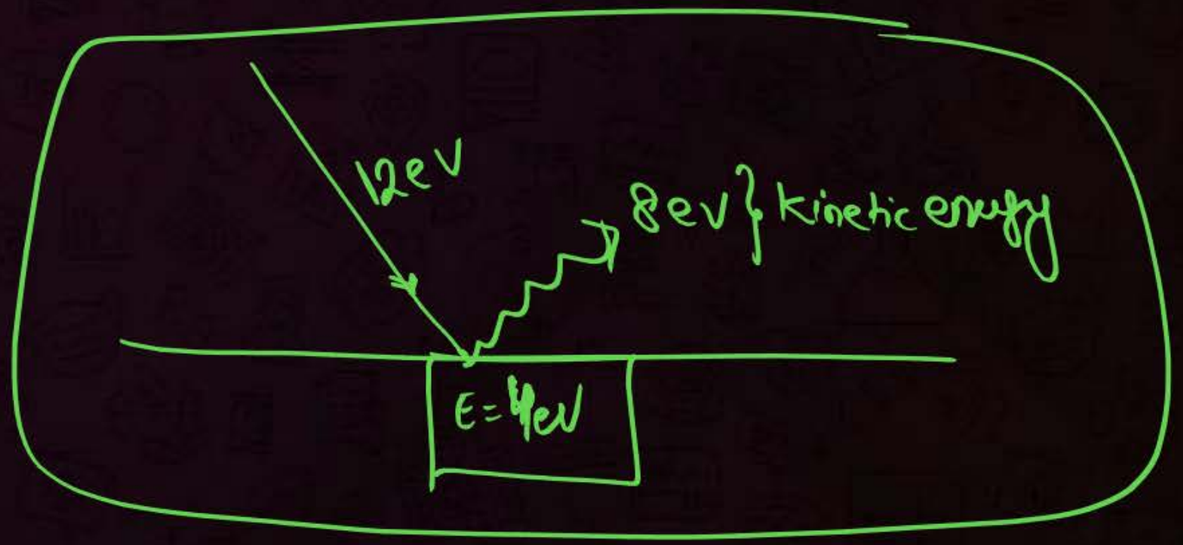
$$E_0/\omega = h\upsilon_0$$

υ_0 → Threshold frequency

$$E_0/\omega = \frac{hc}{\lambda_0}$$

λ_0 → Threshold wavelength





#Einstein

Conservation of energy is applied

incident energy = Threshold energy + Kinetic energy of photoelectrons

$\{E = E_0/w + K.E\}$

$h\upsilon = h\upsilon_0 + K.E$

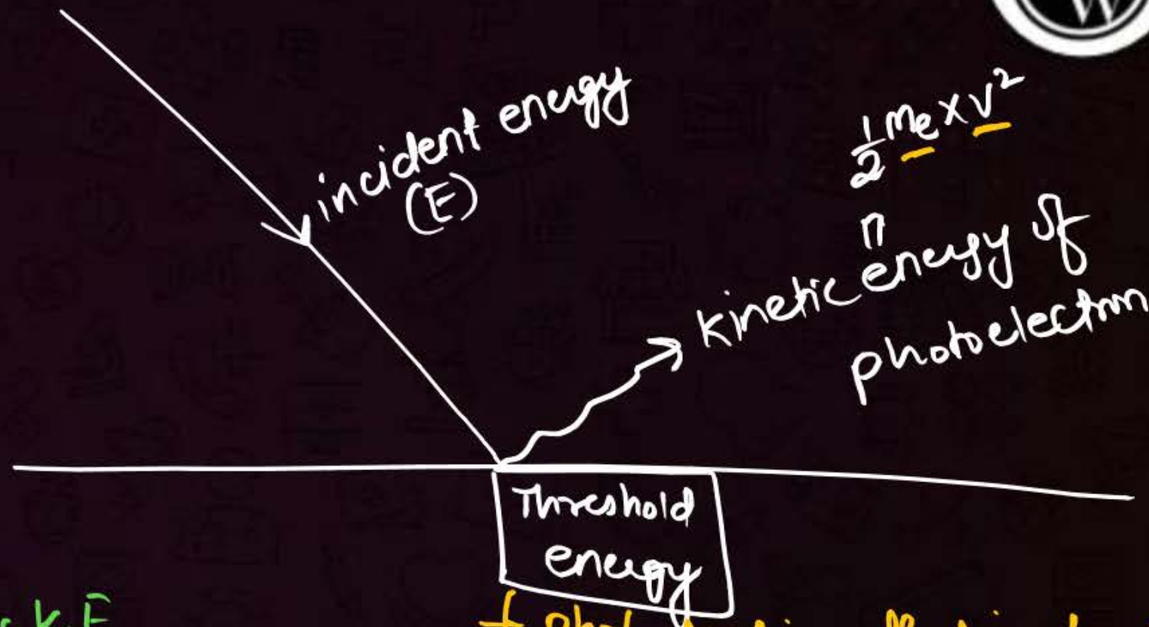
$K.E = h\upsilon - h\upsilon_0$

$\boxed{K.E. = h(\upsilon - \upsilon_0)}$

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

$K.E = \frac{hc}{\lambda} - \frac{hc}{\lambda_0} = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)$

$\boxed{K.E = hc\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)}$



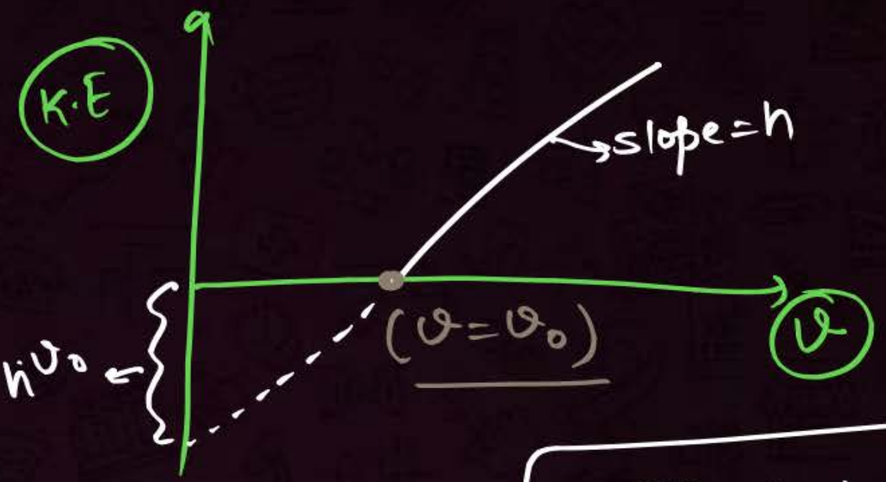
⇒ Photoelectric effect is observed when ($K.E = +ve$)

1. incident energy > Threshold energy
2. incident frequency > Threshold frequency ($\upsilon > \upsilon_0$)
3. incident wavelength < threshold wavelength ($\lambda < \lambda_0$)

$K.E = h\upsilon - h\upsilon_0$

y-axis

x-axis



if intensity is increased,

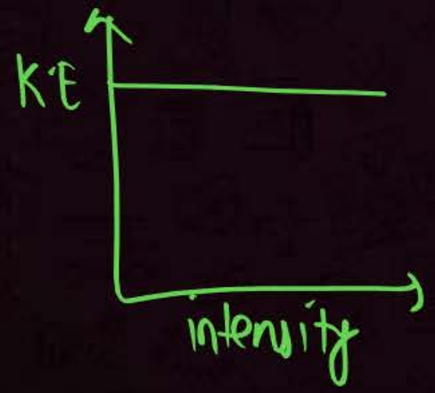
no. of photons increases.

incident energy increases.

Kinetic energy remains constant.

no. of photoelectrons ejected increases.

photoelectric current increases.



NOTE - 1 photon with sufficient energy will release one photoelectron

for n-photons

$n h\upsilon = n h\upsilon_0 + n \times \left(\frac{1}{2} m v^2\right)$

$h\upsilon = h\upsilon_0 + \frac{1}{2} m v^2$

$K.E = h\upsilon - h\upsilon_0 = h(\upsilon - \upsilon_0)$

$K.E = h(\upsilon - \upsilon_0)$

if frequency is tripled, then K.E will be (a) tripled

(b) more than triple

(c) less than triple

(d) Ye sab Moh maya hai.

Sol: initially $\upsilon = 10\ Hz$

$\upsilon_0 = 2\ Hz$

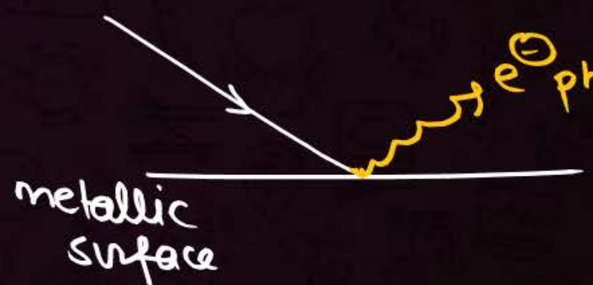
$K.E_{initial} = h(10-2) = 8h$

finally $\upsilon = 30\ Hz$

$\upsilon_0 = 2\ Hz$

$K.E_{final} = h(30-2) = 28h$

#



Stopping energy = kinetic energy

Charge on $e^{\ominus}$ x stopping potential = $K.E = eV_s$

$$V_s = \frac{K.E}{e}$$

NCERT

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, (also known as threshold frequency) below which photoelectric effect is not observed. At a frequency, the ejected electrons come out with certain kinetic energy. The kinetic energies of these electrons increase with the increase of frequency of the light used.

QUESTION

NCERT

K.E = 0

Electrons are emitted with zero velocity from a metal surface when it is exposed to radiation of wavelength 6800 Å. Calculate threshold frequency and work function (W_0) of the metal.

Sol:

incident energy = Threshold energy (W)

$$\frac{hc}{\lambda} = \frac{20 \times 10^{-26}}{6800 \times 10^{-10}} = \frac{1}{340} \times 10^{-16}\ J$$

$$= 0.0029 \times 10^{-16}\ J$$

$$W = E \Rightarrow 2.9 \times 10^{-19}\ J$$

$$\upsilon_0 = \frac{W}{h} = \frac{2.9 \times 10^{-19}}{6.6 \times 10^{-34}}$$

$$\upsilon_0 = 0.439 \times 10^{+15}$$

$$\Rightarrow 4.4 \times 10^{+14}\ Hz$$

QUESTION

The threshold frequency for a metal is $7.0 \times 10^{14}\ s^{-1}$. Calculate the kinetic energy of an electron emitted when radiation of frequency = $1.0 \times 10^{15}\ s^{-1}$ hits the metal.

10×10^{14}

Sol:

$$KE = h(\upsilon - \upsilon_0)$$

$$= h(10 \times 10^{14} - 7 \times 10^{14})$$

$$\Rightarrow h \times 3 \times 10^{14}$$

$$\Rightarrow 6.6 \times 10^{-34} \times 3 \times 10^{14}$$

$$\Rightarrow 20 \times 10^{-20}$$

$$\Rightarrow 2 \times 10^{-19}\ J$$

QUESTION

The threshold frequency for the ejection of electrons from potassium metal is $5.3 \times 10^{14}\ s^{-1}$. Will the photon of a radiation having energy 3.3×10^{-19} J exhibit photoelectric effect? ($h = 6.626 \times 10^{-34}$ Js).

A. Occur

B. Not occur

C. Cannot decide

D. Both A and B

$$W = h\upsilon_0 = 6.6 \times 10^{-34} \times 5.3 \times 10^{14}$$
$$= 34.98 \times 10^{-20}\ J$$
$$= 3.498 \times 10^{-19}\ J$$

$W > E$ → no P.E. effect

QUESTION

The threshold frequency n_0 for a metal is $6 \times 10^{14}\ s^{-1}$. Calculate the kinetic energy of an electron emitted when radiation of frequency = $1.1 \times 10^{15}\ s^{-1}$ hits the metal.

(A) 3.313×10^{-19} J

(B) 2.13×10^{-19} J

(C) 5.53×10^{-19} J

(D) 3.313×10^{-14} J

$K.E = h(\upsilon - \upsilon_0)$

$= 6.6 \times 10^{-34} (11 \times 10^{14} - 6 \times 10^{14})$

$= 6.6 \times 10^{-34} \times 5 \times 10^{14}$

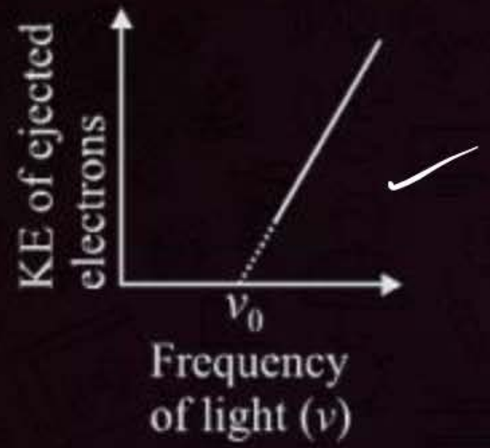
$= 33.0 \times 10^{-20}$

$\Rightarrow 3.3 \times 10^{-19}$ J

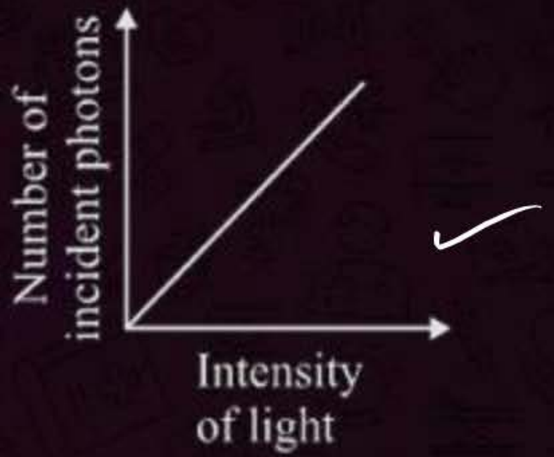
QUESTION

Which of the following is an incorrect graphical representation based on photoelectric effect?

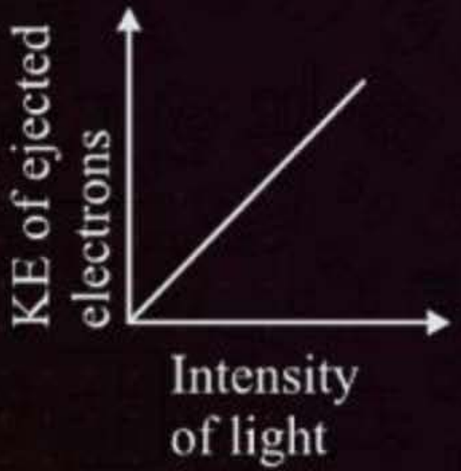
A



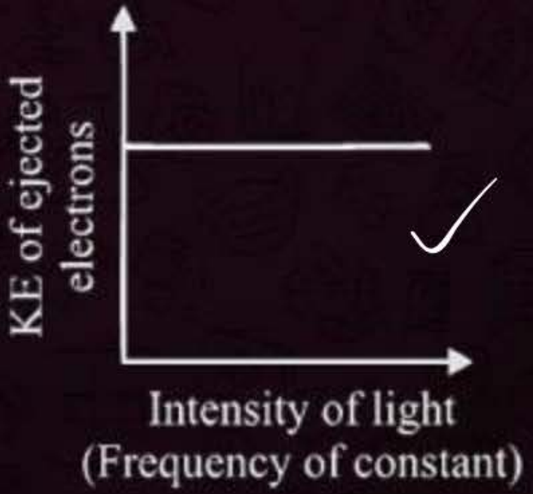
B



C



D



QUESTION

When the frequency of the incident radiation on a metallic plate is doubled, KE of the photoelectrons will be

A Doubled

B Halved

C More than doubled

D Increases but less than doubled

QUESTION

In photoelectric effect the number of photo-electrons emitted is proportional to:

A. Intensity of incident beam

B. Frequency of incident beam

C. Velocity of incident beam

D. Work function of photo-cathode

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

QUESTION

What is the work function of the metal, n the light of wavelength 4000 Å generates photoelectron of velocity 6×10^5 ms^{-1} from it?
(Mass of electron = 9×10^{-31} kg
Velocity of light = 3×10^8 ms^{-1}
Planck's constant = 6.626×10^{-34} Js
Charge of electron = 1.6×10^{-19} JeV^{-1})

(A) 4.0 eV

(B) 2.1 eV

(C) 0.9 eV

(D) 3.1 eV

$$\text{incident energy} = \frac{1240}{4000} = 3.1 \text{ ev}$$

$$K.E = \frac{1}{2} \times m_e \times v^2 = \frac{1}{2} \times 9.1 \times 10^{-31} \times 36 \times 10^{10}$$

$$\Rightarrow 18 \times 9.1 \times 10^{-21} \text{ J}$$

$$\Rightarrow \frac{18 \times 9.1 \times 10^{-21}}{1.6 \times 10^{-19}} \text{ ev}$$

$$\Rightarrow 102.37 \times 10^{-2} \text{ eV}$$

$$\Rightarrow 1.02 \text{ ev}$$

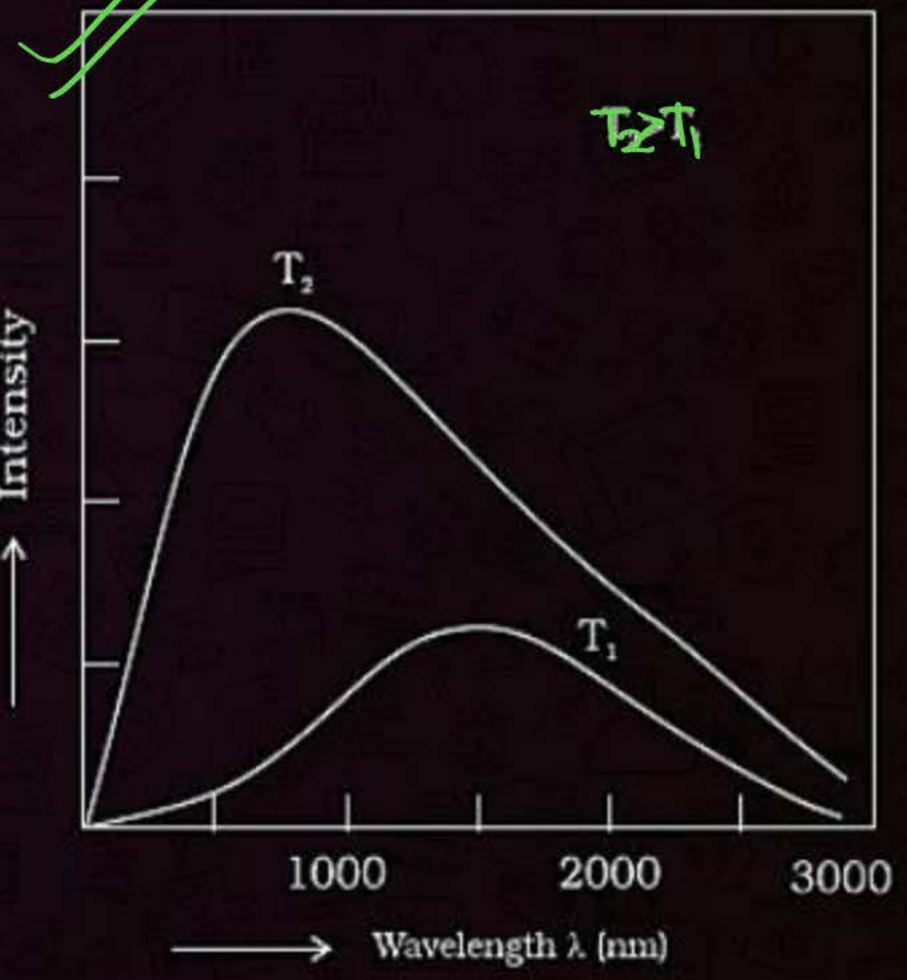
Threshold energy $= E - KF$
$\Rightarrow 3.1 - 1.02$
$\Rightarrow 2.1 \text{ ev}$

Black Body Radiation

$\lambda \cdot T = \text{constant}$

Hot objects emit electromagnetic radiations over a wide range of wavelengths. At high temperatures, an appreciable proportion of radiation is in the visible region of the spectrum. As the temperature is raised, a higher proportion of short wavelength is generated.

At a given temperature, intensity of radiation emitted increases with the increase of wavelength, reaches a maximum value at a given wavelength and then starts decreasing with further increase of wavelength.



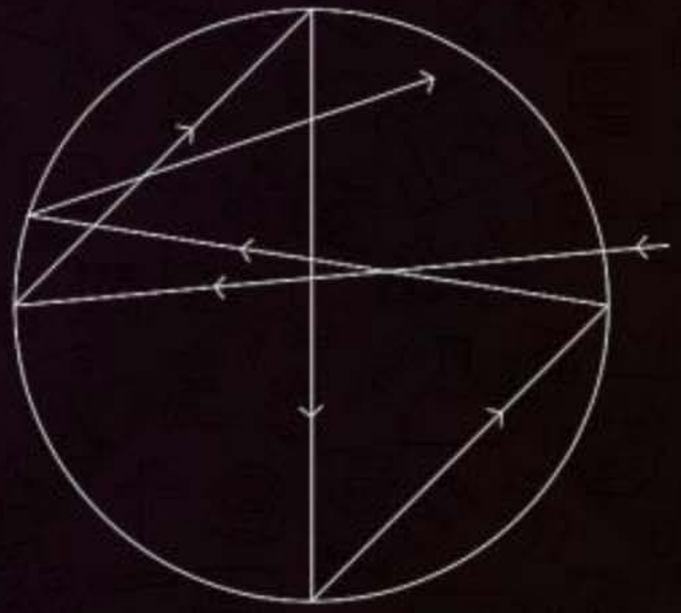
For example, when an iron rod is heated in a furnace, it first turns to dull red and then progressively becomes more and more red as the temperature increases. As this is heated further, the radiation emitted becomes white and then becomes blue as the temperature becomes very high.

This means that red radiation is most intense at a particular temperature and the blue radiation is more intense at another temperature.

NOTE: Intensities of radiations of different wavelengths emitted by hot body depend upon its temperature.

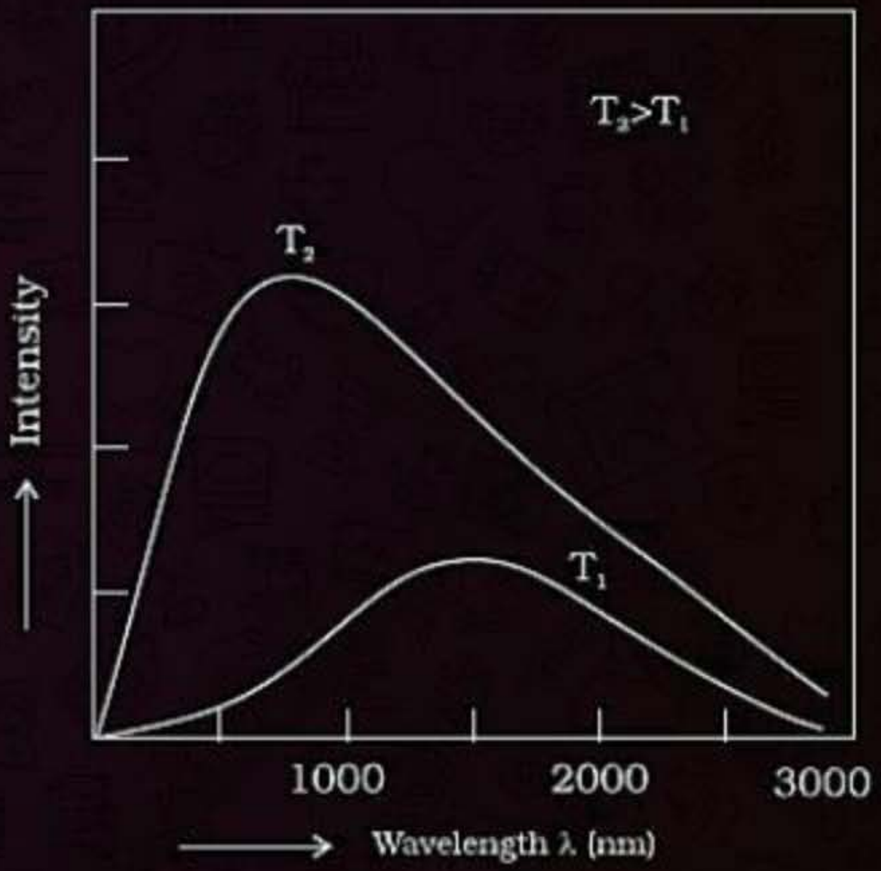
Black Body

- An ideal body, which emits and absorbs radiations of all frequencies uniformly, is called a black body and the radiation emitted by such a body is called black body radiation.
- In practice, no such body exists.
- Carbon black approximates fairly closely to black body.



The amount of light emitted (intensity of radiation) from a black body and its spectral distribution depends only on its temperature.

A black body is also a perfect radiator of radiant energy. Furthermore, a black body is in thermal equilibrium with its surroundings. It radiates same amount of energy per unit area as it absorbs from its surrounding in any given time.



QUESTION

Which of the given statements correctly represents the effect of rise in temperature on the emitted radiations of a hot body?

A. The radiations move towards shorter wavelengths

B. The radiations move towards shorter frequency

C. The radiations move towards lower energy

D. The frequency of radiations does not change

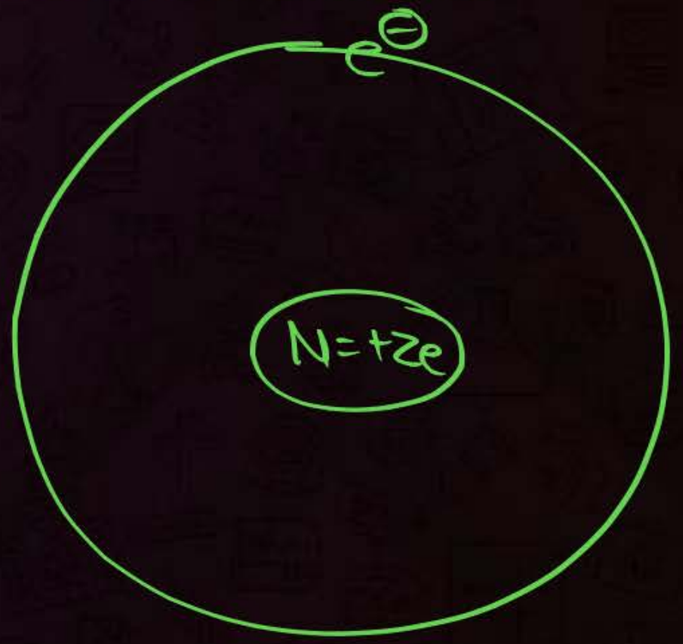
Bohr's Model

- This model was based on quantum theory of radiation and classical laws of physics.
- Bohr model is applicable only for single electron species like H, He^{+}, Li^{2+} etc.
- Bohr model is based on particle nature of electron.

Bohr's atom ⇒ Z = 1 → 'H' atom

Bohr's orbit ⇒ n = 1

Bohr's radius = radius of first orbit of H-atom



QUESTION

Bohr's theory is not applicable to

(A) He $\rightarrow e^{\ominus} = 2$

(B) $Li^{+2} \rightarrow e^{\ominus} = 3 - 2 = 1$

(C) $He^{+2} \rightarrow e^{\ominus} = 2 - 2 = 0$

(D) A and C both

Important Postulates

1st Postulate:

- Atom has a nucleus where all protons and neutrons are present.
- The size of nucleus is very small and it is present at the centre of the atom.

2nd Postulate:

- Negatively charged electron revolve around the nucleus in the same way as the planets revolve around the sun.
- The path of electron is circular.
- The attraction force (Coulombic or electrostatic force) between nucleus and electron is equal to the centrifugal force on electron.

$$\frac{K(ze)(e)}{r^2} = \frac{mv^2}{r}$$

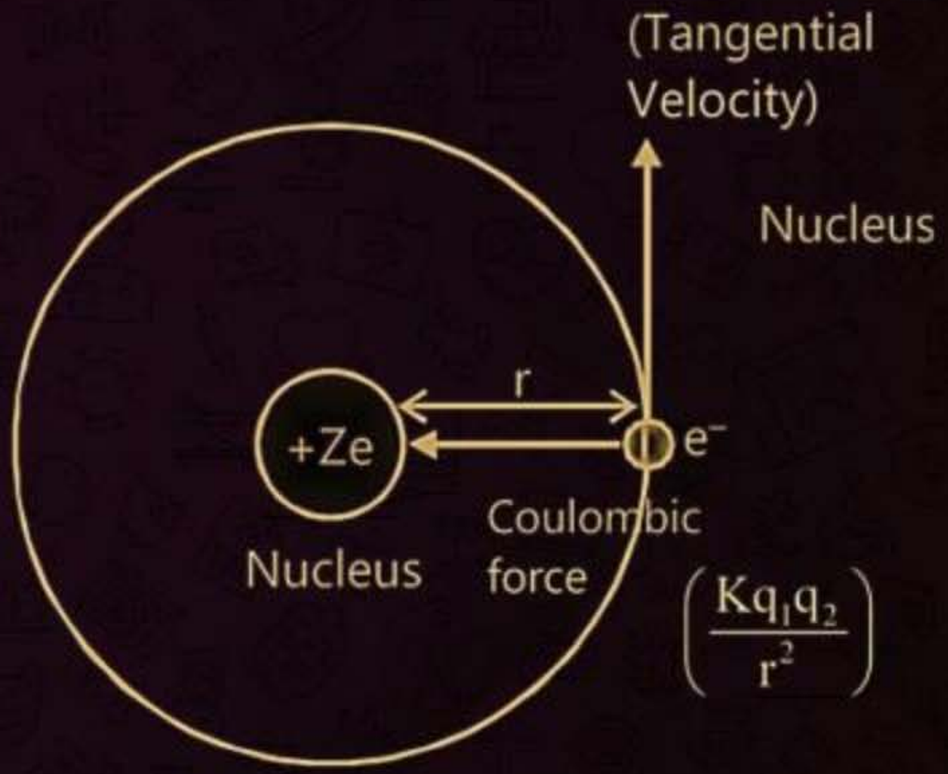
Important Postulates

3rd Postulate:

- Electrons can revolve only in those orbits in which angular momentum (mvr) of electron is integral multiple of $\frac{h}{2\pi} = \hbar$

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

where $n = 1, 2, 3, 4 - - -$



$$\frac{K(Ze)(e)}{r^2} = \frac{mv^2}{r} \Rightarrow \frac{KZe^2}{r^2} = \frac{mv^2}{r} \Rightarrow r = \frac{KZe^2}{mv^2}$$

$$mvr = \frac{nh}{2\pi} \rightarrow r = \frac{nh}{2\pi mv}$$

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

$$\frac{KZe^2}{V} = \frac{nh}{2\pi}$$

$$V = \frac{2\pi KZe^2}{nh} = \left(\frac{2\pi Ke^2}{h}\right)\frac{Z}{n}$$

Put values of all constant

Velocity of $e^\ominus$ in n^{th} orbit $= V_n = 2.18 \times 10^6 \frac{Z}{n}$ m/s

$$\Rightarrow r = \frac{nh}{2\pi mv} = \frac{nh}{2\pi m \times \frac{2\pi Ke^2 Z}{nh}}$$

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

Put all constant values

Radius of n^{th} orbit $= (r_n) = 0.53 \frac{n^2}{Z} A^\circ$

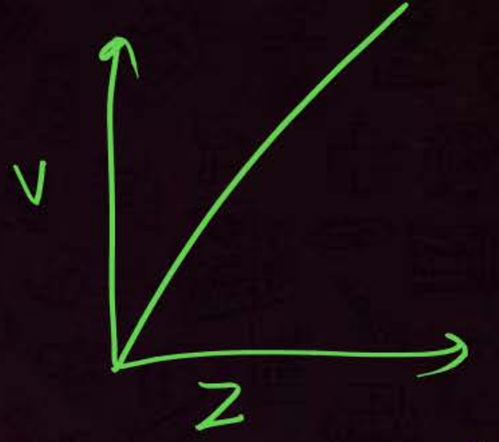
$= 52.9 \times \frac{n^2}{Z}$ pm

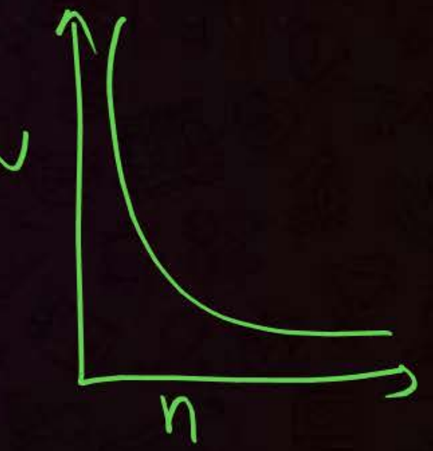
$$V_n = 2.18 \times 10^6 \frac{Z}{n} \text{ m/s}$$

$$r_n = 0.529 \times \frac{n^2}{Z} A^\circ = 52.9 \frac{n^2}{Z} \text{ pm}$$

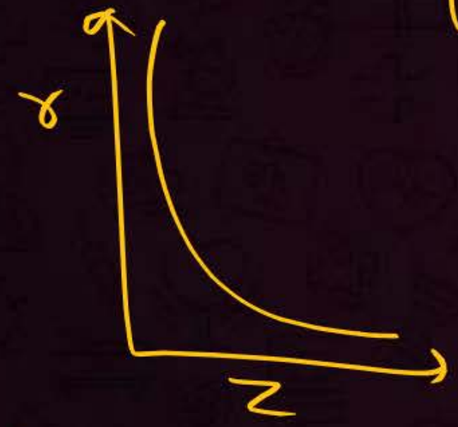
$$V \propto \frac{Z}{n}$$

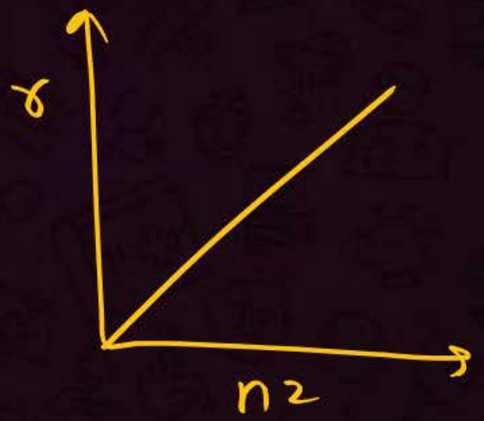
$$\left\{ \frac{V_1}{V_2} = \frac{\left(\frac{Z_1}{n_1}\right)}{\left(\frac{Z_2}{n_2}\right)} \right\}$$

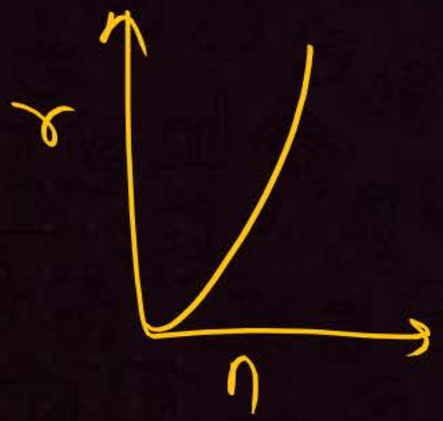




$$r \propto \frac{n^2}{Z}$$







$$\frac{r_1}{r_2} = \frac{\left(\frac{n_1^2}{Z_1}\right)}{\left(\frac{n_2^2}{Z_2}\right)}$$

QUESTION

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

Calculate the radius ratio of 3rd & 5th orbit of He^+.

$V \propto \frac{Z}{n}$

Sol:-

$$\frac{(r_3)_{He^{\oplus}}}{(r_5)_{He^{\oplus}}} = \frac{\left(\frac{3^2}{2}\right)}{\left(\frac{5^2}{2}\right)} = \frac{9}{25}$$

$$\frac{(V_3)_{He^{\oplus}}}{(V_5)_{He^{\oplus}}} = \frac{\left(\frac{2}{3}\right)}{\left(\frac{2}{5}\right)} = \frac{5}{3}$$

QUESTION

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

Calculate the radius ratio of 2nd orbit of hydrogen and 3rd orbit of Li^{+2}.

Sol:

$$\frac{(r_2)_H}{(r_3)_{Li^{+2}}} = \frac{\left(\frac{2^2}{1}\right)}{\left(\frac{3^2}{3}\right)} = \frac{4 \times 3}{9_3} = \frac{4}{3}$$

$V \propto \frac{Z}{n}$

$$\frac{(V_2)_H}{(V_3)_{Li^{+2}}} = \frac{\left(\frac{1}{2}\right)}{\left(\frac{3}{3}\right)} = \frac{1}{2}$$

QUESTION

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

If the radius of first orbit of H-atom is x Å, then the radius of the second orbit of Li^{2+} ion will be

A) x Å

B) $\frac{4x}{3}$ Å

C) $\frac{9x}{2}$ Å

D) 4x Å

$$\frac{(r_2)_{Li^{+2}}}{(r_1)_H} = \frac{\left(\frac{2^2}{3}\right)}{\left(\frac{1^2}{1}\right)} = \frac{4}{3}$$

$$(r_2)_{Li^{+2}} = \frac{4}{3}(r_1)_H = \frac{4}{3} \times x$$

QUESTION

$V \propto \frac{Z}{n}$

If velocity of an electron in Ist orbit of H atom is V, what will be the velocity of electron in 3rd orbit of Li^{+2}:

A V

B V/3

C 3 V

D 9 V

$$\frac{(V_3)_{Li^{+2}}}{(V_1)_H} = \frac{\left(\frac{3}{3}\right)}{\left(\frac{1}{1}\right)} = 1$$

$$(V_3)_{Li^{+2}} = (V_1)_H = V$$

QUESTION

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

If r_1 is the radius of the first orbit of hydrogen atom, then the radii of second, third and fourth orbits in terms of r_1 are

(A) r_1^2, r_1^3, r_1^4

(B) $8r_1, 27r_1, 64r_1$

(C) $4r_1, 9r_1, 16r_1$

(D) $2r_1, 6r_1, 8r_1$

$r_1 = x$

$r_2 = 2^2 \times x = 4r_1$

$r_3 = 3^2 \times x = 9r_1$

$r_4 = 4^2 \times x = 16r_1$

QUESTION

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

In which of the following radius of the first orbit is minimum?

$\downarrow r \propto \frac{1}{Z\uparrow}$

(A) A Hydrogen atom $(Z=1)$

(B) A tritium atom $(Z=1)$

(C) Triply ionized beryllium $(Z=4)$

(D) Double ionized helium $(Z=2)$

$r_n = 0.529 \frac{n^2}{Z}\ A^\circ$

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

circumference of n^{th} orbit $= 2\pi r_n = C_n$

$\text{circumference} \propto r_n \propto \frac{n^2}{Z}$

$\text{Time period} = \frac{2\pi r_n}{V_n}$

$T \propto \frac{r_n}{V_n} \propto \left(\frac{n^2}{Z}\right)\left(\frac{Z}{n}\right)$

$\text{Time period} \propto \frac{n^3}{Z^1}$

$\text{frequency} = \frac{1}{T}$

$\text{frequency} \propto \frac{Z^1}{n^3}$

QUESTION

$C \propto r_n \propto \frac{n^2}{Z}$

The ratio of circumference of third and second orbits of He^+ ion is

$$\frac{(C_3)_{He^+}}{(C_2)_{He^+}} = \frac{\left(\frac{3^2}{2}\right)}{\left(\frac{2^2}{2}\right)} = \frac{9}{4}$$

A 3 : 2

B 2 : 3

C 9 : 4

D 4 : 9

QUESTION

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

The ratio of time taken by electron in revolutions round the H-nucleus in the second and third orbits is

$$\frac{(T_2)_H}{(T_3)_H} = \frac{\left(\frac{2^3}{1^2}\right)}{\left(\frac{3^3}{1^2}\right)} = \frac{8}{27}$$

A 2 : 3

B 4 : 8

C 8 : 27

D 27 : 8

QUESTION

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

Calculate the radius ratio of 2nd & 4th orbit of Li^{+2}

A) 1 : 2

B) 2 : 5

C) 1 : 4

D) 3 : 4

$$\frac{(r_2)_{Li^{+2}}}{(r_4)_{Li^{+2}}} = \frac{\left(\frac{2^2}{3}\right)}{\left(\frac{4^2}{3}\right)} = \frac{4}{16} = \frac{1}{4}$$

QUESTION

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

Calculate the radius ratio of 4^{th} orbit of He^{+} and 3^{rd} orbit of Be^{+3}

A) 32 : 9

B) 9 : 32

C) 16 : 9

D) 9 : 16

$$\frac{(r_4)_{He^+}}{(r_3)_{Be^{+3}}} = \frac{\left(\frac{4^2}{2}\right)}{\left(\frac{3^2}{4}\right)} = \frac{16}{2} \times \frac{4}{9} = \frac{32}{9}$$

QUESTION

For any H like system, the ratio of velocities of I, II & III orbit i.e. V_1, V_2, V_3 will be

$V \propto \frac{Z}{n}$

$V_I : V_{II} : V_{III} = \frac{1}{1} : \frac{1}{2} : \frac{1}{3}$

A) 1 : 2 : 3

B) 1 : ½ : 1/3

C) 3 : 2 : 1

D) 1 : 1 : 1

QUESTION

Calculate the angular momentum of 3^{rd} orbit of Li^{+2}?

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

(A) $\frac{3h}{2\pi}$

(B) $\frac{h}{2\pi}$

(C) $\frac{5h}{2\pi}$

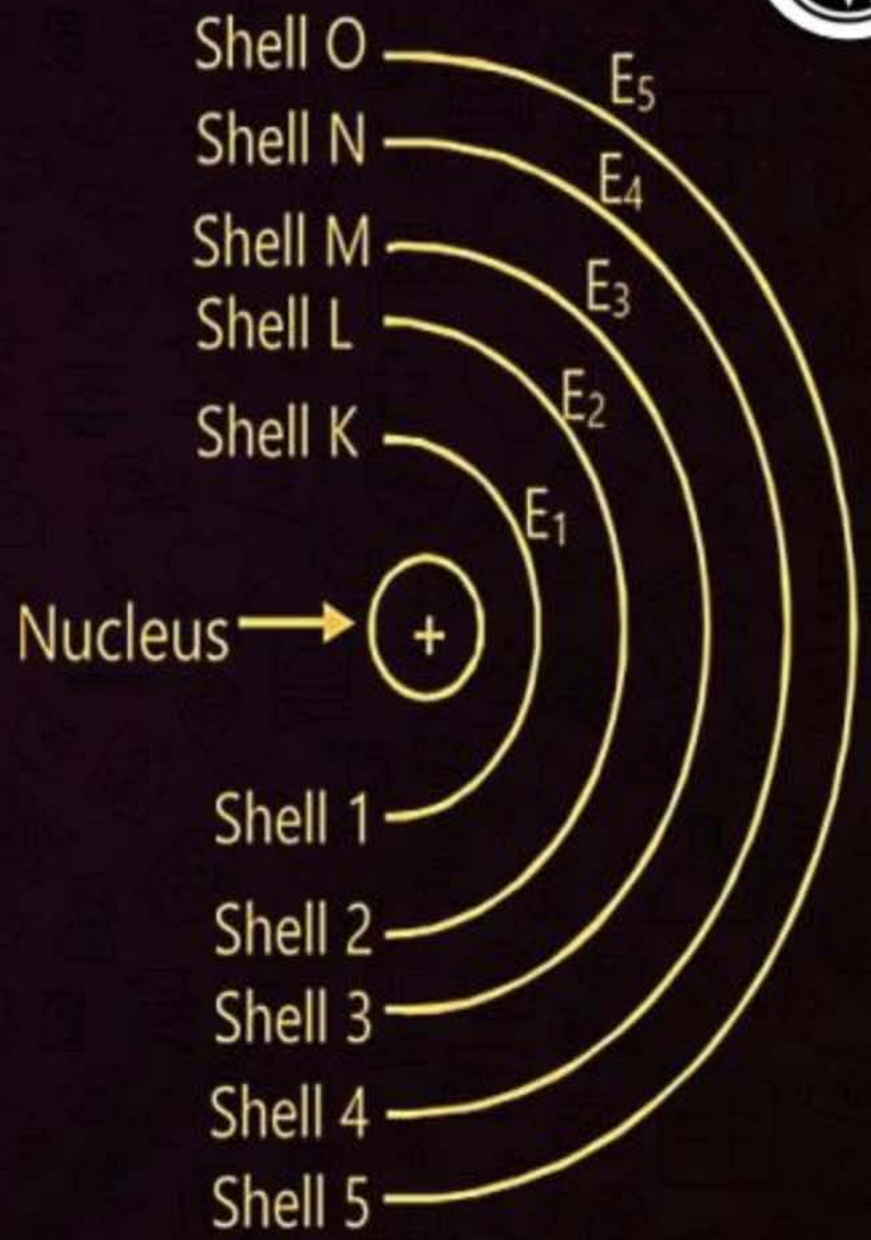
(D) $\frac{7h}{2\pi}$

4th Postulate:

- The orbits in which electron can revolve are known as stationary orbits because in these orbits energy of electron is always constant.

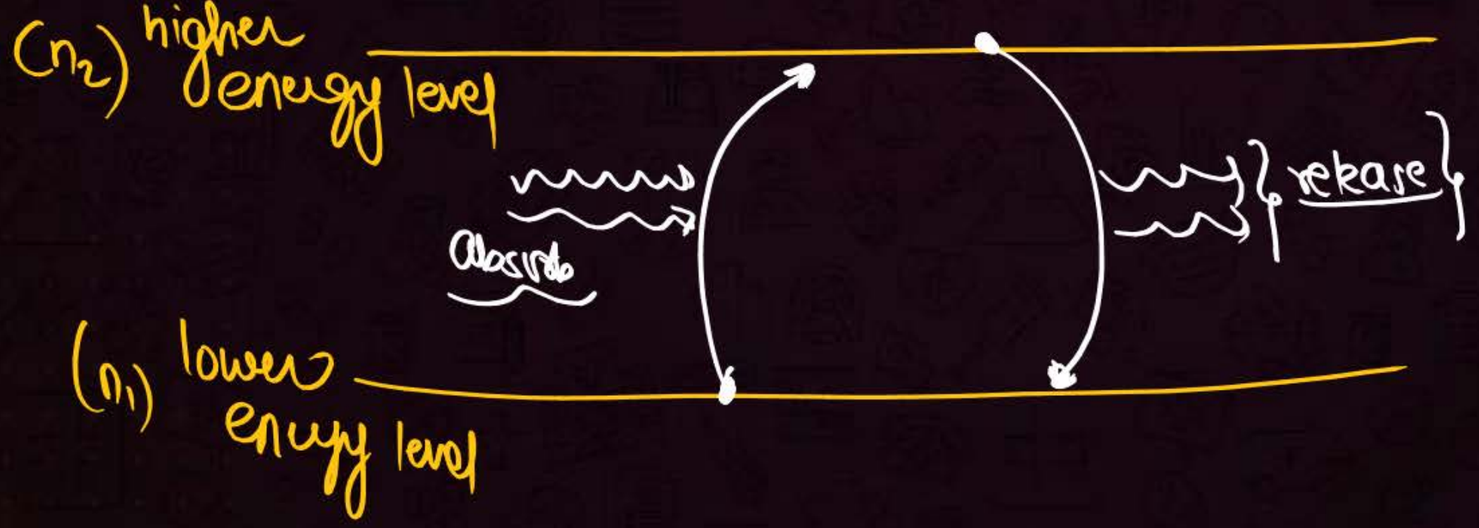
5th Postulate:

- Each stationary orbit is associated with definite amount of energy therefore these orbits are also called as energy levels and are numbered as 1, 2, 3, 4, 5, ... or K, L, M, N, O, ... from the nucleus outwards.



6th Postulate:

- The emission or absorption of energy in the form of photon can only occur when electron jumps from one stationary state to another.
- Energy is absorbed when electron jumps from inner to outer orbit and is emitted when electron moves from outer to inner orbit.



Potential energy $(P.E) = \frac{K(+Ze)(-e)}{r} = -\frac{KZe^2}{r}$

Kinetic energy $(K.E) = \frac{1}{2}mv^2 = \frac{1}{2}\frac{KZe^2}{r}$

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

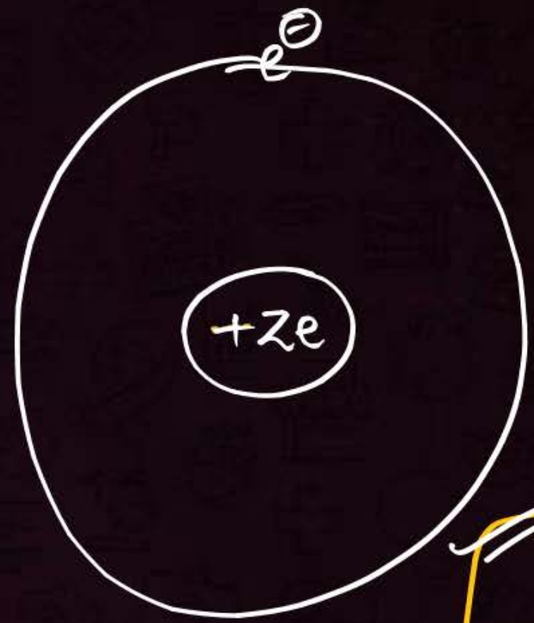
$$mv^2 = \frac{KZe^2}{r}$$

Total energy $(T.E) = P.E + K.E$

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

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

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



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

$$T.E = -K.E$$

$$T.E = \frac{1}{2} \times P.E$$

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

$$K.E = +\frac{1}{2}\frac{kze^2}{r}$$

$$T.E = -\frac{1}{2}\frac{kze^2}{r}$$

Put all constant values,

Total energy of n^{th} orbit $= E_n = -13.6\frac{z^2}{n^2}$ ev/atom

$$E_n = -2.18\times10^{-18}\frac{z^2}{n^2}\ J/atom$$

$E \propto \frac{z^2}{n^2}$

$E_\infty = 0$

H-atom $\rightarrow z=1$

$E_1 = -13.6$ eV

$E_2 = -\frac{13.6}{4} = -3.4$ ev

$E_3 = -\frac{13.6}{9} = -1.51$ ev

$E_4 = -\frac{13.6}{16} = -0.85$ ev

$E_5 = -\frac{13.6}{25} = -0.54$ ev

→ no. of orbit increases

→ Total energy increases

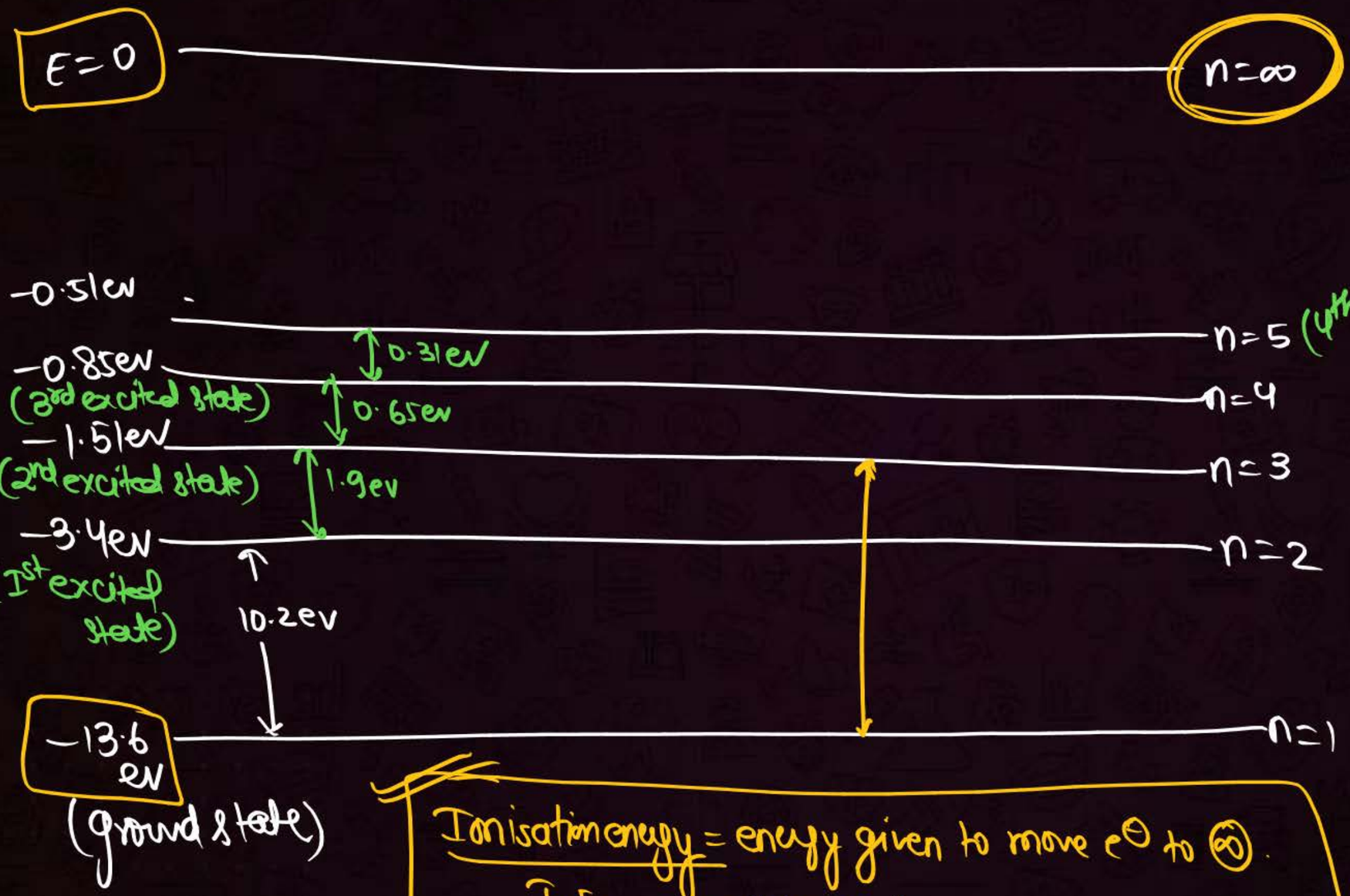
→ energy gap b/w two consecutive orbits decreases

$E_2 - E_1 = 10.2$ ev

$E_3 - E_2 = 1.9$ ev

$E_4 - E_3 = 0.65$ ev

$E_5 - E_4 = 0.31$ ev



Ionisation energy = energy given to move $e^{\ominus}$ to ∞.

$I.E = -E_n = +13.6\frac{Z^2}{n^2}$ eV/atom

$E_3 - E_1 = -1.51 - (-13.6)$

$= -1.51 + 13.6$

$= +12.1$

$(E_3 - E_2) + (E_2 - E_1)$

n = 6 or P	$E_6 = -0.38$ eV	
n = 5 or O	$E_5 = -0.54$ eV	
n = 4 or N	$E_4 = -0.85$ eV	$E_5 - E_4 = 0.31$ eV
n = 3 or M	$E_3 = -1.51$ eV	$E_4 - E_3 = 0.66$ eV
n = 2 or L	$E_2 = -3.4$ eV	$E_3 - E_2 = 1.89$ eV
n = 1 or K	$E_1 = -13.6$ eV	$E_2 - E_1 = 10.2$ eV

QUESTION

Energy of orbit

A. Increases as we move away from nucleus

B. Decreases as we move away from nucleus

C. Remains same as we move away from nucleus

D. None of these

QUESTION

The value of the energy for the first excited state of hydrogen atom will be

$n=2$

$E_n = -13.6\frac{Z^2}{n^2}$ ev/atom

A. –13.6 eV

B. –3.40 eV

C. –1.51 eV

D. –0.85 eV

QUESTION

$E \propto \frac{Z^2}{n^2}$

The ratio of energies of first excited state of He^+ ion and ground state of H-atom is

($n=2$) ($n=1$)

(A) 1 : 1

(B) 4 : 1

(C) 1 : 4

(D) 16 : 1

$$\frac{(E_2)_{He^+}}{(E_1)_H} = \frac{\left(\frac{2^2}{2^2}\right)}{\left(\frac{1^2}{1^2}\right)} = \frac{1}{1}$$

QUESTION

Magnitude of K.E. in an orbit is equal to

A Half of the potential energy

B Twice of the potential energy

C One fourth of the potential energy

D None of these

$K.E = \frac{1}{2}\frac{kze^2}{r}$

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

QUESTION

Calculate the radius of 3rd excited state of Li^{+2}.

(n=4)

(A) 2.82 Å

(B) 4.52 Å

(C) 7.23 Å

(D) 1.75 Å

$$(r_4)_{Li^{+2}} = 0.53 \times \frac{4^2}{3}$$

$$\Rightarrow 0.53 \times \frac{16}{3}$$

$$= 2.82 A^{\circ}$$

QUESTION

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

Calculate the radius ratio of 2nd excited state of H & 1st excited state of Li^{+2}.

(n=3) (n=1)

A) 9 : 4

B) 27 : 4

C) 16 : 9

D) 25 : 9

$$\frac{(r_3)_H}{(r_2)_{Li^{+2}}} = \frac{\left(\frac{3^2}{1}\right)}{\left(\frac{2^2}{3}\right)} = \frac{9}{1} \times \frac{3}{4} = \frac{27}{4}$$

QUESTION

If the total energy of an electron is –1.51 eV in hydrogen atom then find out K.E, P.E, orbit's radius and velocity of the electron in that orbit.

Sol:

$$T.E = -1.51\ eV$$
$$K.E = +1.51\ eV$$
$$P.E = 2 \times T.E \Rightarrow -3.02\ eV$$

$$\pm 1.51 = \mp 13.6 \times \frac{1^2}{n^2}$$

$$n^2 = \frac{13.6}{1.51} = 9$$

$$\boxed{n = 3}$$

$$(r_3)_H = 0.53 \times \frac{3^2}{1}\ A^\circ$$

$$(V_3)_H = 2.18 \times 10^6 \times \frac{1}{3}\ m/s.$$

QUESTION

Calculate the energy of Li^{+2} ion for 2nd excited state

$n = 3$

Sol

$$(E_3)_{Li^{+2}} = -13.6 \times \frac{3^2}{3^2}$$

$$\Rightarrow -13.6\ eV$$

QUESTION

Calculate the ratio of energies of He^+ for 1st & 2nd excited state.

Sol: $E \propto \frac{Z^2}{n^2}$

$$\frac{(E_2)_{He^+}}{(E_3)_{He^{\oplus}}} = \frac{\left(\frac{2^2}{2^2}\right)}{\left(\frac{2^2}{3^2}\right)} = \frac{9}{4}$$

QUESTION

If the total energy of an electron is -0.54 eV in hydrogen atom then find out P.E. of the electron in that orbit

(A) –1.08 eV

(B) 0.27 eV

(C) –0.54 eV

(D) 2.16 eV

$P.E = 2 \times T.E$

$= 2 \times -0.54$

$=$

QUESTION

The energy needed to excite a hydrogen atom from its ground to its third excited state is

(ground: $n=1$; third excited state: $n=4$)

A. 12.1 eV

B. 10.2 eV

C. 0.85 eV

D. 12.75 eV

$E_1 = -13.6$ eV

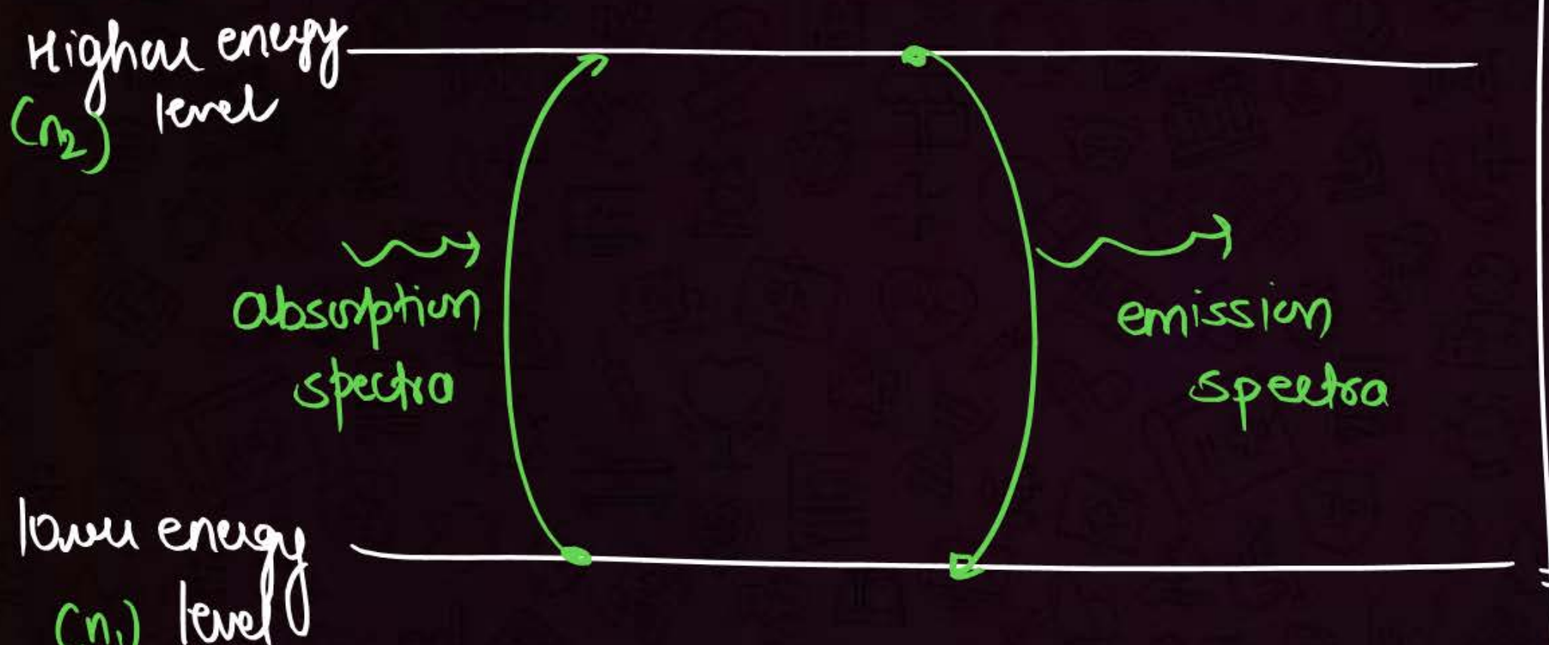
$E_4 = \frac{-13.6}{16} = -0.85$ eV

$\Delta E = E_4 - E_1 = -0.85 + 13.6$

$\Rightarrow 12.75$ eV

n = 6 or P	$E_6 = -0.38$ eV	
n = 5 or O	$E_5 = -0.54$ eV	
n = 4 or N	$E_4 = -0.85$ eV	$E_5 - E_4 = 0.31$ eV
n = 3 or M	$E_3 = -1.51$ eV	$E_4 - E_3 = 0.66$ eV
n = 2 or L	$E_2 = -3.4$ eV	$E_3 - E_2 = 1.89$ eV
n = 1 or K	$E_1 = -13.6$ eV	$E_2 - E_1 = 10.2$ eV

Hydrogen Spectra



$n_2 \longrightarrow n_1$

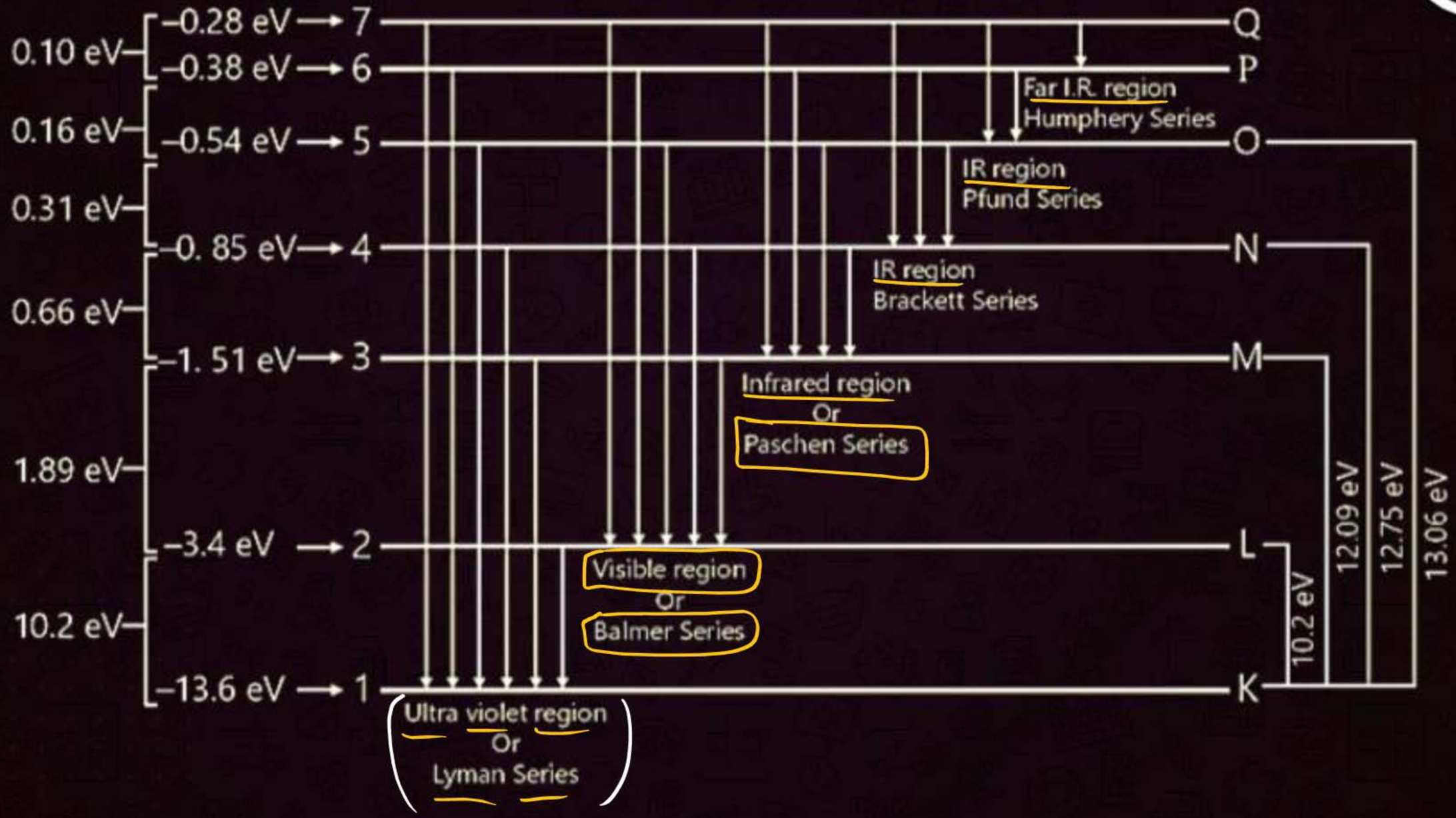
$$\Rightarrow \frac{1}{\lambda} = \bar{v} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

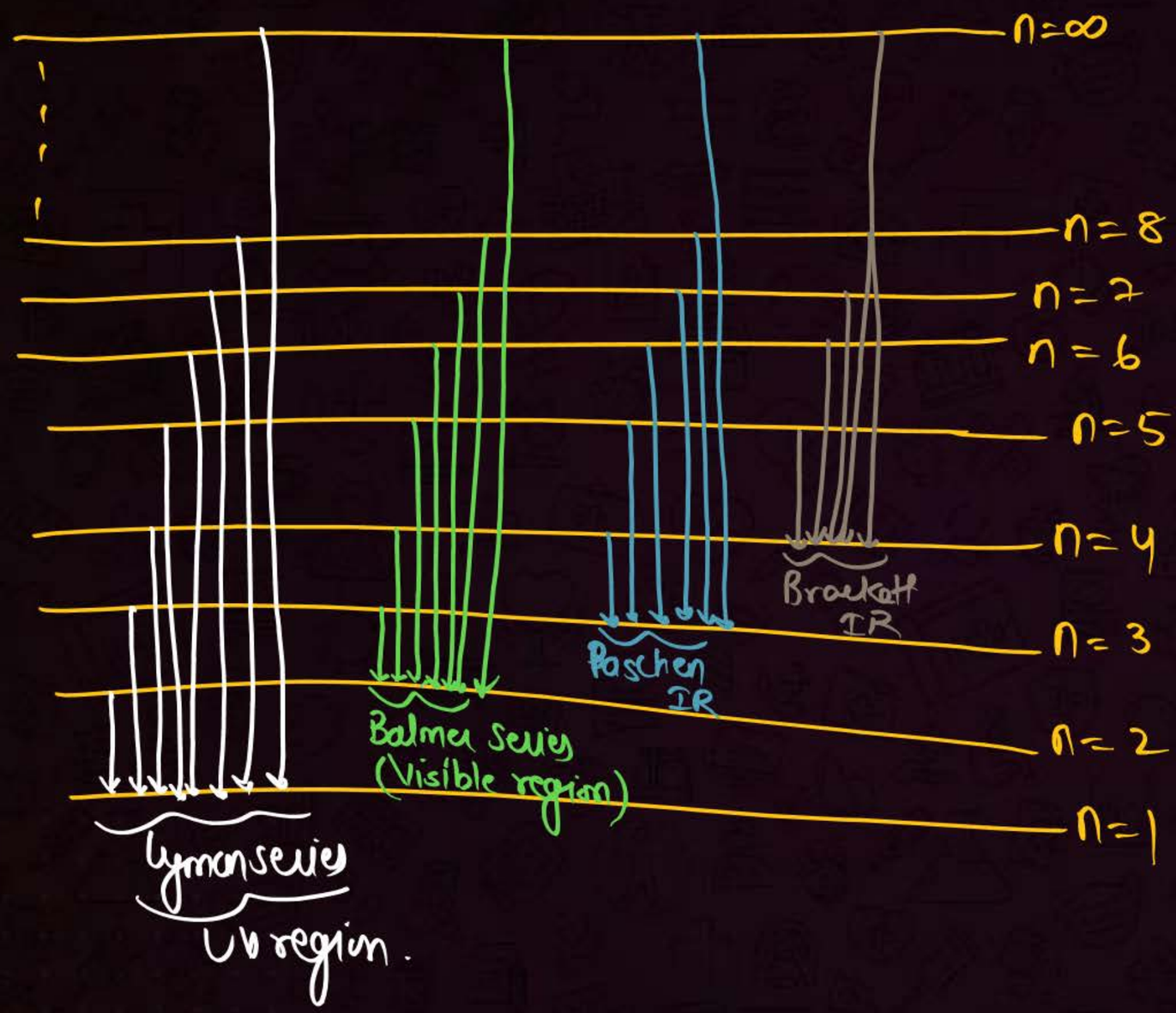
where R = Rydberg's constant

$R = 109677\ (cm^{-1})$

for numericals $\frac{1}{R} = 912\ A^\circ$

$\Rightarrow$ total no. of spectral lines $= \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$


−0.28 eV → 7
−0.38 eV → 6
−0.54 eV → 5
−0. 85 eV → 4
−1. 51 eV → 3
−3.4 eV → 2
−13.6 eV → 1
0.10 eV
0.16 eV
0.31 eV
0.66 eV
1.89 eV
10.2 eV
Q
P
O
N
M
L
K
Far I.R. region
Humphery Series
IR region
Pfund Series
IR region
Brackett Series
Infrared region
Or
Paschen Series
Visible region
Or
Balmer Series
Ultra violet region
Or
Lyman Series
10.2 eV
12.09 eV
12.75 eV
13.06 eV



For lyman series

↳ I^st / α-line ⇒ (2) → (1)

min energy / min frequency / max. wavelength.

2nd line / β-line ⇒ (3) → (1)

3rd line / γ-line ⇒ (4) → (1)

last line / limiting line / max. energy / max. frequency / min λ

(∞) → (1)

Series	Discovered by	Regions	n_2	n_1
Lyman	Lyman	U.V. region	$n_2 = 2, 3, 4.../n_1 = 1$	$n_1 = 1$
Balmer	Balmer	Visible region	$n_2 = 3, 4, 5.../n_1 = 2$	$n_1 = 2$
Paschen	Paschen	Infra red (I.R.)	$n_2 = 4, 5, 6.../n_1 = 3$	$n_1 = 3$
Brackett	Brackett	I.R. region	$n_2 = 5, 6, 7.../n_1 = 4$	$n_1 = 4$
Pfund	Pfund	I.R. region	$n_2 = 6, 7, 8.../n_1 = 5$	$n_1 = 5$
Humphery	Humphery	Far I.R. region	$n_2 = 7, 8, 9.../n_1 = 6$	$n_1 = 6$

⇒ no. of spectral lines of any particular series = $n_2 - n_1$ → of that particular series.

Q Calculate wavelength of emission light when an $e^{\ominus}$ form $n_2 = 4$ to $n_1 = 2$ transition takes place in $He^{\oplus}$ atom. Also calculate (a) total no. of spectral lines.
(b) spectral lines belonging to lyman and Balmer.

Sol: $He^{\oplus}$; $n_2 = 4$ → $n_1 = 2$

$$\frac{1}{\lambda} = R \times 2^2 \left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

$$\frac{1}{\lambda} = 4R \left(\frac{1}{4} - \frac{1}{16}\right)$$

$$\frac{1}{\lambda} = 4R \times \frac{3}{16} \quad 4$$

$$\lambda = \frac{4}{3R} = \frac{4}{3} \times 912\ A^0$$

⇒ total no. of spectral lines $= \frac{(4-2)(4-2+1)}{2}$

$\Rightarrow \frac{2 \times 3}{2} = 3$

⇒ spectral lines belongs to lyman series = 0

spectral lines belongs to Balmer series = 4 − 2

⇒ 2

QUESTION

In hydrogen spectrum, the series of lines appearing in ultraviolet region of electromagnetic spectrum are called

A Lyman lines

B Balmer lines

C Pund lines

D Brackett lines

QUESTION

Which of the following series of lines in the atomic spectrum of hydrogen appear in the visible region?

A Lyman

B Paschen

C Brackett

D Balmer

QUESTION

When electron jumps from the fourth orbit to the second orbit in He^+ ion, the radiation emitted out will fall in

A Ultraviolet region

B Visible region

C Infrared region

D Radio wave region

QUESTION

To which electronic transition between Bohr orbits in hydrogen, the second line in the Balmer series belongs?

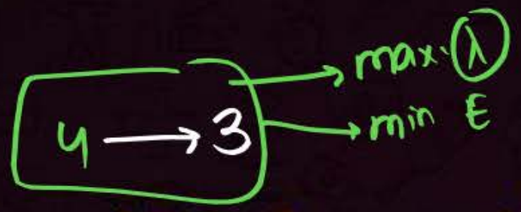
A) 3 to 2 → 1st line

B) 4 to 2 → 2nd line

C) 5 to 2

D) 6 to 2

QUESTION



Wavelength of the first line of Paschen series is

A [18750] A^0

B [2854] A^0

C [3452] A^0

D [6243] A^0

$$\frac{1}{\lambda} = R \times 1^2 \times \left(\frac{1}{3^2} - \frac{1}{4^2}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{1}{9} - \frac{1}{16}\right) = R\left(\frac{16-9}{16\times 9}\right) = \frac{7R}{16\times 9}$$

$$\lambda = \frac{144}{7} \times \frac{1}{R} = \frac{144}{7} \times 912\ A^0$$

QUESTION

Calculate wavelength of 3rd line of Brackett series in hydrogen spectrum

(7 → 4)

A. $\frac{784}{33R}$

B. $\frac{33R}{784}$

C. $\frac{784R}{33}$

D. $\frac{33}{784R}$

$$\frac{1}{\lambda} = R \times 1^2 \left(\frac{1}{4^2} - \frac{1}{7^2}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{1}{16} - \frac{1}{49}\right)$$

$$\frac{1}{\lambda} = R \times \frac{33}{16 \times 49}$$

$$\lambda = \frac{16 \times 49}{33R}$$

QUESTION

What is the maximum wavelength line in the Lyman series of He^+ ion?

(A) $3R$

(B) $\frac{1}{3R}$

(C) $\frac{4}{4R}$

(D) None of these

$2 \longrightarrow 1$

$\frac{1}{\lambda} = R \times 2^2 \left(\frac{1}{1^2} - \frac{1}{2^2}\right)$

$\frac{1}{\lambda} = 4R\left(1 - \frac{1}{4}\right) = 4R \times \frac{3}{4}$

$\lambda = \frac{1}{3R}$

QUESTION

The number of possible spectral lines in Brackett series in hydrogen spectrum, when the electrons present in the ninth excited state return to the ground state, is

($n_2 = 10$)

($n_1 = 1$)

A 36

B 45

C 5

D 6

total no. of spectral lines $= \frac{(10-1)(10-1+1)}{2}$

$\rightarrow \frac{9 \times 10}{2} = 45$

Brackett series lines $\Rightarrow 10-4$

$\Rightarrow 6$

QUESTION

Ratio between longest wavelength of H atom in Lyman series to the shortest wavelength in Balmer series of He^+ is

(λ_{max}) ($2 \longrightarrow 1$)

(λ_{min}) ($\infty \longrightarrow 2$)

A) 4/3

B) 36/5

C) 1/4

D) 5/9

$$\frac{\lambda_{max}}{\lambda_{min}} = \frac{\frac{4}{3R}}{\frac{1}{R}} = \frac{4}{3}$$

H-atom

$$\frac{1}{\lambda_{max}} = R \times 1^2 \left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\frac{1}{\lambda_{max}} = R \times \left(1 - \frac{1}{4}\right) = \frac{3R}{4}$$

$$\lambda_{max} = \frac{4}{3R}$$

$He^{\oplus}$ ion

$$\frac{1}{\lambda_{min}} = R \times 2^2 \left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$$\frac{1}{\lambda_{min}} = 4R \times \frac{1}{4} = R$$

$$\lambda_{min} = \frac{1}{R}$$

QUESTION

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

[JEE Main 2019]

A non linear

B linear with slope $-R_H$

C linear with slope R_H

D linear with intercept $-R_H$

$$\frac{1}{\lambda} = \bar{\nu} = R\left(\frac{1}{n^2} - \frac{1}{8^2}\right)$$

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

y-axis

x-axis

Slope = R

y-intercept $= -\frac{R}{64}$

Limitations of the Bohr's Model

(1) Bohr's theory does not explain the spectrum of multi electron atom/ion.

(2) Why the Angular momentum of the revolving electron is equal to $nh/2\pi$ has not been explained by Bohr's theory.

(3) Bohr inter related quantum theory of radiation and classical laws of physics without any theoretical explanation.

(4) Bohr's theory does not explain the fine structure of the spectral lines. Fine structure of the spectral line is obtained when spectrum is viewed by spectroscope of more resolution power.

(5) Bohr's theory does not explain the splitting of spectral lines in the presence of magnetic field (Zeeman's effect) or electric field (Stark effect)

QUESTION

Splitting of spectral lines when atoms are subjected to strong electric field is called:

A Zeeman effect

B Stark effect

C Decay

D Disintegration

QUESTION

Zeeman effect is due to

A splitting up the lines in an emission spectrum in the presence of an external electrostatic field

B random scattering of light by colloidal particles

C splitting up of the lines in an emission spectrum in a magnetic field

D emission of electrons from metals when light falls upon them

QUESTION

Limitations of Bohr's model is/are

(A) it fails to account for the finer details of the hydrogen atom spectrum observed by using sophisticated spectroscopic techniques

(B) it is unable to explain the spectrum of atoms other than hydrogen

(C) it is unable to explain the ability of atoms to form molecules by chemical bonds

(D) All of the above

Debroglie's Hypothesis

$\lambda \propto \frac{1}{\text{momentum}\ (p)}$

$\lambda \propto \frac{1}{p} \propto \frac{1}{mv}$

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

kg, m/s

matter waves



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

$K.E = \frac{p^2}{2m}$

$p^2 = 2mK.E$

$p = \sqrt{2mK.E}$

in terms of K.E.

$\lambda = \frac{h}{\sqrt{2mK.E}}$

in terms of voltage

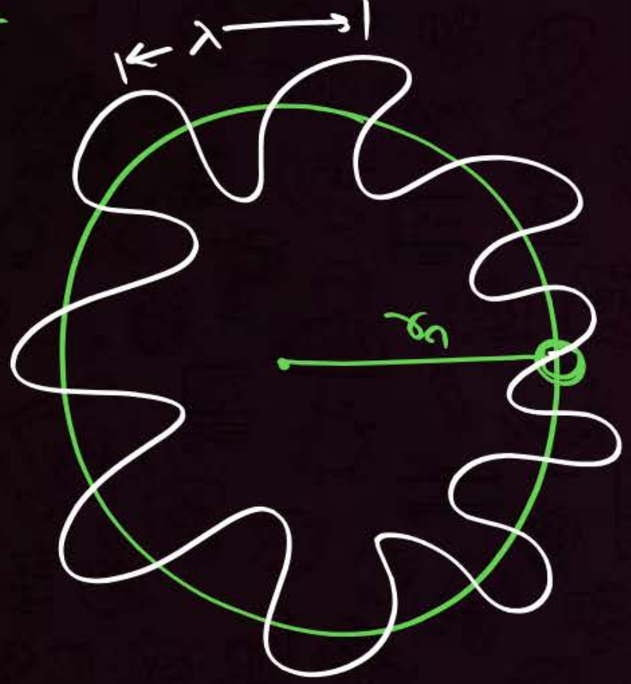
$\lambda = \frac{h}{\sqrt{2mQV}}$

$p = \sqrt{2mQ.V}$

charge, voltage

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mK.E}} = \frac{h}{\sqrt{2mQ.V}}$$

for n^{th} orbit, no. of waves $= n$



Circumference $= 2\pi r_n = n\lambda$

$$2\pi r = \frac{nh}{mv}$$

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

QUESTION

Minimum de-Broglie wavelength is associated with

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

A Electron

B Proton

C CO_2 molecule

D SO_2 molecule

QUESTION

The de Broglie wavelength of a tennis ball mass 60 g moving with a velocity of 10 m per second is approximately:

$m = \frac{60}{1000} = 6 \times 10^{-2}$ kg

$v = 10$ m/s.

$\lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{6 \times 10^{-2} \times 10}$

$\Rightarrow 1.1 \times 10^{-33}$ m

(A) 10^{-16} m

(B) 10^{-25} m

(C) 10^{-33} m

(D) 10^{-31} m

QUESTION

An electron is moving with a kinetic energy of 4.55×10^{-25} J. What will be de Broglie wavelength for this electron?

(A) 5.28×10^{-7} m

(B) 7.28×10^{-7} m

(C) 2×10^{-10} m

(D) 3×10^{-5} m

$$\lambda = \frac{h}{\sqrt{2mKE}} = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 4.55 \times 10^{-25}}}$$

$$= \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-28}}$$

$$\rightarrow 0.725 \times 10^{-6}$$

$$\rightarrow 7.25 \times 10^{-7}$$

QUESTION

In H-atom, if 'x' is the radius of the first Bohr orbit, de Broglie wavelength of an electronic 3rd orbit is

(A) $3\pi x$

(B) $6\pi x$

(C) $\frac{9x}{2}$

(D) $\frac{x}{2}$

$n=3$

$2\pi r_3 = 3\lambda$

$2\pi \times 3^2 \times r_1 = 3\times\lambda$

$18\pi x = 3\lambda$

$\lambda = 6\pi x$

QUESTION

What possibly can be the ratio of the de-Broglie wavelengths for two electrons each having zero initial energy and accelerated through 50 volts and 200 volts

A) 3 : 10

B) 10 : 3

C) 1 : 2

D) 2 : 1

$$\lambda = \frac{h}{\sqrt{2mQ \cdot V}}$$

$$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{V_2}{V_1}}$$

$$\frac{\lambda_1}{\lambda_2} = \sqrt{\frac{200}{50}} = \frac{2}{1}$$

Heisenberg's Uncertainity Principle

↳ valid only microscopic objects

It is impossible to experimentally determine simultaneously the exact position and actual momentum of a minute particle like an electron.

Δx = uncertainity in position

$m\Delta V = \Delta P$ = Uncertainity in momentum

↳ uncertainity in velocity

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

for numericals

$$\Delta x \cdot \Delta P = \frac{h}{4\pi}$$

$$\Delta x \cdot m\Delta V \geq \frac{h}{4\pi}$$

ΔE = Uncertainity in energy

Δt = Uncertainity in time

$$\Delta t \cdot \Delta x \cdot m\frac{\Delta V}{\Delta t} \geq \frac{h}{4\pi}$$

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

QUESTION

Uncertainty in position is twice the uncertainty in momentum. Uncertainty in velocity is

(A) $\sqrt{\frac{\hbar}{\pi}}$

(B) $\frac{1}{2m}\sqrt{\frac{\hbar}{\pi}}$

(C) $\frac{1}{2m}\sqrt{\hbar}$

(D) $\frac{\hbar}{4\pi}$

$\Delta x = 2\Delta p$

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

$2\Delta p \cdot \Delta p = \frac{h}{4\pi}$

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

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

$\Delta v = \sqrt{\frac{\hbar}{4m^2}} = \frac{1}{2m}\sqrt{\hbar}$

QUESTION

Uncertainty in position of a 0.25 g particle is 10^{-5}. Uncertainty of velocity is ($h = 6.6 \times 10^{-34}$ J s)

$m = \frac{0.25}{1000} = 0.25 \times 10^{-3}$ kg

$\Delta x = 10^{-5}$

(A) 1.2×10^{34}

(B) 2.1×10^{-26}

(C) 1.6×10^{-20}

(D) 1.7×10^{-9}

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

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

$\Delta v = \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 0.25 \times 10^{-3} \times 10^{-5}}$

$\rightarrow \frac{6.6}{3.14} \times 10^{-26}$

QUESTION

A microscope using suitable photons is employed to locate an electron in an atom within a distance of 0.1 Å. What is the uncertainty involved in the measurement of its velocity?

$(\Delta x = 0.1 A^\circ = 0.1 \times 10^{-10} m \rightarrow 10^{-11} m)$

(A) $2.69 \times 10^6 \, ms^{-1}$

(B) $5.79 \times 10^5 \, ms^{-1}$

(C) $5.79 \times 10^6 \, ms^{-1}$

(D) $4.62 \times 10^6 \, ms^{-1}$

$$\Delta V = \frac{h}{4\pi m \Delta x} = \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 10^{-11}}$$

$$\Delta V = \frac{6.6}{4 \times 3.14 \times 9.1} \times 10^{+8}$$

$$= 0.0577 \times 10^8$$

$$= 5.77 \times 10^6 \, m/s$$

QUESTION

A golf ball has a mass of 40 g, and a speed of 45 ms^{-1}. If the speed can be measured with in accuracy of 2%, calculate the uncertainty in the position.

(A) 2.52×10^{-33} m

(B) 3.02×10^{-33} m

(C) 1.46×10^{-33} m

(D) 0.82×10^{-33} m

$m = \frac{40}{1000} = 4 \times 10^{-2}$ kg

$\left(\Delta V = \frac{2}{100} \times 45 = 0.9 \text{ m/s}\right)$

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

$= \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 4 \times 10^{-2} \times 0.9}$

$\Rightarrow 0.145 \times 10^{-32}$

$\Rightarrow 1.45 \times 10^{-33}$ m

QUESTION

If the uncertainty in position of a moving particle is 0 then find out ΔP

A 0

B 1

C Infinite

D None of these

$$\Delta p = \frac{h}{4\pi \Delta x}, \quad \Delta x \to 0$$

$$\Delta p = \infty$$

QUESTION

Uncertainty in measuring the speed of a particle is numerically equal to the uncertainty in measuring its position. The value of these uncertainties will be

(A) Equal to $\sqrt{\frac{h}{4\pi m}}$

(B) Less than $\sqrt{\frac{h}{4\pi m}}$

(C) Greater than $\sqrt{\frac{h}{4\pi m}}$

(D) Both (A) or (C)

$\Delta V = \Delta x$

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

$\Delta x^2 \geq \frac{h}{4\pi m}$

$\Delta x \geq \sqrt{\frac{h}{4\pi m}}$

Atomic Models



Solid sphere model (Dalton, 1803)

Plum pudding model (Thomson, 1897)

Nuclear model (Rutherford, 1911)

Planetary model (Bohr 1913)

Quantum model (Schrodinger, 1926)

Schrodinger's Equation

electron → wave nature
electron → particle nature

$\frac{\partial}{\partial x}$ → partial differentiation w.r.t x

$\frac{\partial^2}{\partial x^2}$ → partial double differentiation w.r.t x

→ pronounced as psi

ψ = wavefunction

ψ^2 = probability density of finding an $e^\ominus$

$\psi^2 dv$ = probability of finding an $e^\ominus$

dv = small volume = $dx \cdot dy \cdot dz$

Schrodinger's equation ⇒

$$\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi^2 m(E-V)\psi}{h^2}=0$$

→ where E = total energy
V = potential energy.

In shortcut $\{\hat{H}\psi = E\psi\}$ where $\hat{H}$ = Hamiltonian operator

Schrodinger's equation has solutions as $\psi_{n,\ell,m}$

based on $\int_{-\infty}^{+\infty} \psi^2 dV = 1 \Rightarrow$

$\psi_{n,\ell,m}$

- n → principal Q.n → orbit/shell
- ℓ → azimuthal/subsidiary Q.N. → Subshell
- m → magnetic Q.N. → orbitals

QUESTION

Which of the following is the correct form of Schrodinger wave equation?

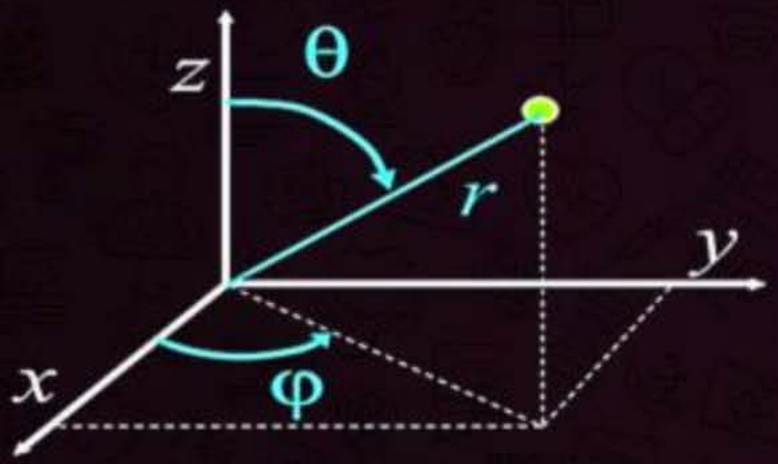
(A) $\frac{\partial^2\psi}{\partial^2 x}+\frac{\partial^2\psi}{\partial^2 y}+\frac{\partial^2\psi}{\partial^2 z}+\frac{16\pi^2 m}{h^2}(E-V)\psi=0$

(B) $\frac{\partial^2\psi}{\partial^2 x}+\frac{\partial^2\psi}{\partial^2 y}+\frac{\partial^2\psi}{\partial^2 z}+\frac{8\pi^2 m}{h^2}(E-V)\psi=0$

(C) $\frac{\partial^2\psi}{\partial^2 x}+\frac{\partial^2\psi}{\partial^2 y}+\frac{\partial^2\psi}{\partial^2 z}+\frac{4\pi^2 m}{h^2}(E-V)\psi=0$

(D) $\frac{\partial^2\psi}{\partial^2 x}+\frac{\partial^2\psi}{\partial^2 y}+\frac{\partial^2\psi}{\partial^2 z}+\frac{8\pi^2 m^2}{h^2}(E-V)\psi=0$

Instead of Cartesian (x, y, z) the maths works out easier if we use a different coordinate system:



$$x = r \sin\theta \cos\varphi$$
$$y = r \sin\theta \sin\varphi$$
$$z = r \cos\theta$$

(takes advantage of the spherical symmetry of the system)

$$\text{let } a_0 = \frac{4\pi \epsilon_0 h^2}{\mu e^2} \approx 0.0529\text{nm}$$

$$\psi_{n,l,ml}$$

$$\downarrow$$

$$\psi_{1,0,0} = \frac{1}{\sqrt{\pi}} \left(\frac{Z}{a_0}\right)^{3/2} e^{-Zr/a_0}$$

$$\psi_{2,0,0} = \frac{1}{4\sqrt{2\pi}} \left(\frac{Z}{a_0}\right)^{3/2} \left(2 - \frac{Zr}{a_0}\right) e^{-Zr/2a_0}$$

$$\psi_{2,1,0} = \frac{1}{4\sqrt{2\pi}} \left(\frac{Z}{a_0}\right)^{3/2} \left(\frac{Zr}{a_0}\right) e^{-Zr/2a_0} \cos(\theta)$$

$$\psi_{2,1,\pm1} = \frac{1}{8\sqrt{2\pi}} \left(\frac{Z}{a_0}\right)^{3/2} \left(\frac{Zr}{a_0}\right) e^{-Zr/2a_0} \sin(\theta) e \pm i\varphi$$

$$\psi_{2,0,0} = \frac{1}{81\sqrt{3\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(27 - 18\frac{Zr}{a_0} + 2\frac{Z^2r^2}{a_0^2}\right)e^{-Zr/3a_0}$$

$$\psi_{3,1,0} = \frac{\sqrt{2}}{81\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(6 - \frac{Zr}{a_0}\right)\frac{Zr}{a_0}e^{-Zr/3a_0}\cos(\theta)$$

$$\psi_{3,1,\pm1} = \frac{1}{81\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(6 - \frac{Zr}{a_0}\right)\frac{Zr}{a_0}e^{-Zr/3a_0}\sin(\theta)e \pm i\varphi$$

$$\psi_{3,2,0} = \frac{1}{81\sqrt{6\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\frac{Z^2r^2}{a_0^2}e^{-Zr/3a_0}(3\cos^2(\theta) - 1)$$

Quantum Numbers

orbit (n) → Subshell (ℓ) → Orbital (m)

↳ set of numbers which gives all information about an $e^{\ominus}$ in an atom.

↳ There are four type of Quantum Numbers

① Principal Q.N (n) ⇒ tells about orbit/shell in which $e^{\ominus}$ is present.

- $r_n = 0.53\frac{n^2}{Z}$, V_n, E_n
- angular momentum = $\frac{nh}{2\pi}$
- Value of n can be positive whole number from 1 to ∞.

Subshell	ℓ
s	0
p	1
d	2
f	3
g	4

② Azimuthal Q.N. (ℓ) ⇒ tells about subshell in which $e^{\ominus}$ is present in any orbit of atom.

- Value of ℓ depends on n.
- tells about orientation of subshell.
- angular momentum of subshell = $\sqrt{\ell(\ell+1)}\frac{h}{2\pi}$

Value of $\ell = 0$ to $(n-1)$ → for a particular orbit

no. of values of ℓ = no. of subshell

for a given (n)

no. of subshells = n

no. of orbitals = n^2

max. $e^{\ominus} = 2n^2$

$n=1 \rightarrow \ell=0 \Rightarrow 1s$

$n=2 \rightarrow \ell=0 \Rightarrow 2s$

$\ell=1 \Rightarrow 2p$

$n=3 \rightarrow \ell=0 \Rightarrow 3s$

$\ell=1 \Rightarrow 3p$

$\ell=2 \Rightarrow 3d$

2d → n=2, $\ell=2$ } not possible

3f → n=3, $\ell=3$ } not possible

angular momentum for s-subshell ($\ell=0$) = $\sqrt{0(0+1)}\,\frac{h}{2\pi} = 0$

" " " p-subshell ($\ell=1$) = $\sqrt{1(1+1)}\,\frac{h}{2\pi} = \frac{\sqrt{2}\,h}{2\pi}$

" " " d-subshell ($\ell=2$) = $\sqrt{2(2+1)}\,\frac{h}{2\pi} = \frac{\sqrt{6}\,h}{2\pi}$

For H-atm / single $e^{\ominus}$ species / Bohr's atm

↳ energy order $\propto$ (n)

$$\underbrace{1s}_{n=1} < \underbrace{2s = 2p}_{n=2} < \underbrace{3s = 3p = 3d}_{n=3} < \underbrace{4s = 4p = 4d = 4f}_{n=4}$$

For multi-electron system :→ energy is decided by Bohr-Bury rule $(n+\ell)$ rule

↳ ① Higher the value of $(n+\ell)$, Higher is the energy

2s < 2p	
$n=2$	$n=2$
$\ell=0$	$\ell=1$
2	3

② if $(n+\ell)$ = same, Higher the value of 'n', higher is the energy.

3d < 4p	
$n=3$	$n=4$
$\ell=2$	$\ell=1$
5	5

(3) Magnetic Quantum No. (m) ⇒ tells about orbital in which an $e^{\ominus}$ is present.

- values of m ⇓ no. of orbitals
- value of (m) depends on (ℓ).
- value of m (for a given (ℓ)) ⇓ $-\ell$ to $+\ell$ including zero

for a given ℓ

no. of orbitals = $2\ell+1$

max. $e^{\ominus}$ = $2(2\ell+1)$ ⇒ $4\ell+2$

	ℓ	m	orbitals	max. $e^{\ominus}$
S-subshell →	0 →	0	→ 1	→ 2
P-subshell →	1 →	−1, 0, +1	→ 3 (−1 0 +1)	→ 6
d-subshell →	2 →	−2, −1, 0, +1, +2	→ 5	→ 10
f-subshell →	3 →	−3, −2, −1, 0, +1, +2, +3	→ 7	→ 14
g-subshell →	4 →	−4 to +4	→ 9	→ 18

		orbitals	max. $e^{\ominus}$
$n=1$	$\ell=0$ (1s) $\rightarrow m=0$	1	2
$n=2$	$\ell=0$ 2s $\rightarrow m=0$	4	8
	$\ell=1$ 2p $\rightarrow m=-1,0,+1$		
$n=3$	$\ell=0$ 3s $\rightarrow m=0$	9	18
	$\ell=1$ 3p $\rightarrow m=-1,0,+1$		
	$\ell=2$ 3d $\rightarrow m=-2,-1,0,+1,+2$		
$n=4$	$\ell=0$ 4s $\rightarrow m=0$	16	32
	$\ell=1$ 4p $\rightarrow m=-1,0,+1$		
	$\ell=2$ 4d $\rightarrow m=-2,-1,0,+1,+2$		
	$\ell=3$ 4f $\rightarrow m=-3,-2,-1,0,+1,+2,+3$		

For a given (n)

no. of subshell = n

no. of orbitals = n^2

max. $e^{\ominus} = 2n^2$

$\psi_{n,\ell,m}$

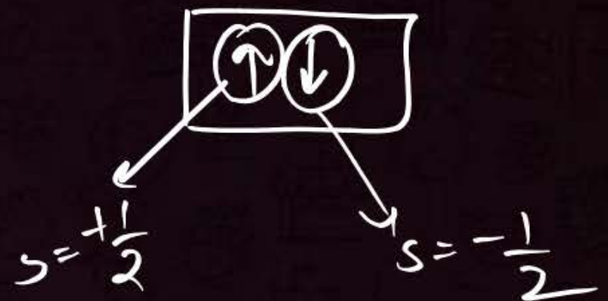
④ Spin Q.N (m_s or s) ⇒ tells about spin of $e^{\ominus}$ around its own axis.

↳ not a part of schrodinger's solution.

→ $s = +\frac{1}{2}$ or $-\frac{1}{2}$

$+\frac{1}{2}$ → Clockwise → anticlockwise

$-\frac{1}{2}$ → Anticlockwise → Clockwise.



spin angular momentum = $\sqrt{s(s+1)}\,\frac{h}{2\pi}$

nodes ⇒ area/region where probability of finding an $e^{\ominus}$ is zero.

Radial nodes ⇓ $(n-l-1)$

angular nodes ⇓ l

total nodes = $n-1$

2p

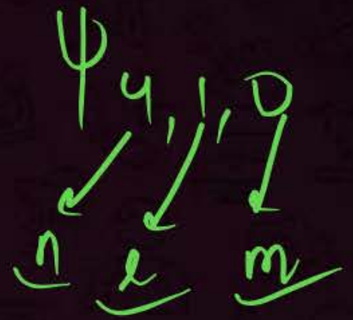
- $n=2$, $l=1$
- radial nodes = $2-1-1=0$
- angular nodes = 1
- total nodes = 1

5p

- radial nodes = $5-1-1=3$
- angular nodes = 1
- total nodes = 4

QUESTION

Which of the following orbital is the complete wave function represented by Ψ_{410}?



A 4s

B 3p

C 4p

D 4d

QUESTION

Which orbital is represented by $\Psi_{4,2,0}$

n l m

A. 4d

B. 3d

C. 4p

D. 4s

QUESTION

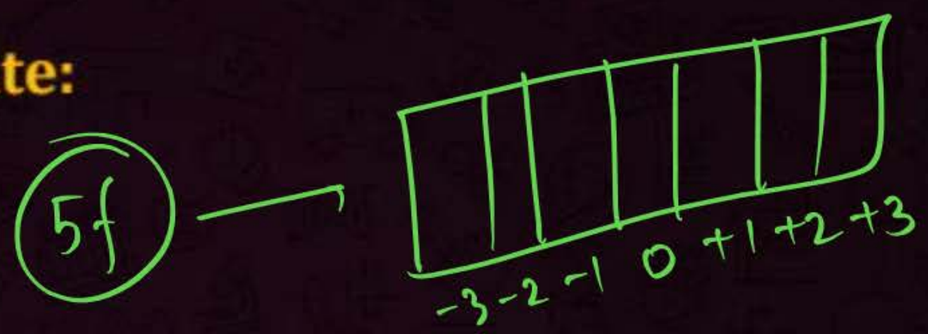
A subshell n = 5, l = 3 can accommodate:

A 10 electrons

B 14 electrons

C 18 electrons

D None of these



QUESTION

The orbital angular momentum of an electron is 2s orbital is

$\ell = 0$

(A) $+\frac{1}{2} \cdot \frac{h}{2\pi}$

(B) 0

(C) $\frac{h}{2\pi}$

(D) $\sqrt{2}\frac{h}{2\pi}$

QUESTION

The orbital angular momentum of a 4p electron will be

(A) $4 \cdot \frac{h}{2\pi}$

(B) $\sqrt{2} \cdot \frac{h}{2\pi}$

(C) $\sqrt{6} \cdot \frac{h}{2\pi}$

(D) $\sqrt{2} \cdot \frac{h}{4\pi}$

4p ↓ $\ell = 1$

$\sqrt{1(1+1)}\,\frac{h}{2\pi} = \frac{\sqrt{2}\,h}{2\pi}$

QUESTION

Which of the following set of quantum numbers is not possible?

(A) $n = 2, \ell = 0, m = 1, s = -\frac{1}{2}$

(B) $n = 3, \ell = 2, m - 0, s = \pm\frac{1}{2}$

(C) $n = 2, \ell = 3, m - 2, s = \pm\frac{1}{2}$

QUESTION

The total number of nodes are given by

A (n + 1)

B (n – l – 1)

C (n – 1)

D (n – l + 1)

QUESTION

Orbital having 3 angular nodes and 3 total nodes is

[NEET (Odisha) 2019]

$l = 3$

$n - l = 3$

$n = 4$

A 5p

B 3d

C 4f

D 6d

QUESTION

The number of radial nodes for 3 p-orbital is.....

3-1-1=1

A 3

B 4

C 2

D 1

Shapes of Orbitals

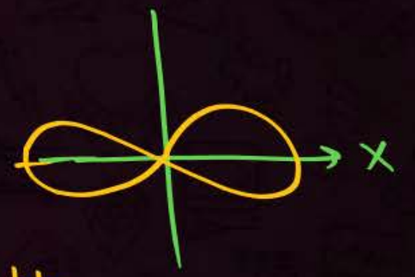
① $l = 0$ → s-subshell → shape = spherical
- $m = 0$
- angular nodes = 0



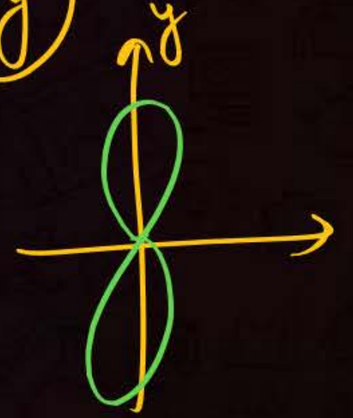
② $l = 1$ → p-subshell → shape = dumb-bell
- 1 angular nodes / nodal plane.
- $m = -1, 0, +1$

$P_z \rightarrow m = 0$
$P_x / P_y \rightarrow -1 / +1$

P_x → nodal plane = yz



P_y → nodal plane = xz



P_z → nodal plane = xy



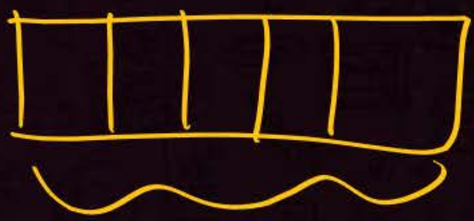
③ $l = 2$ → d-subshell } shape = double dumb-bell

→ $m = -2, -1, 0, +1, +2$

d_{z^2}, $d_{x^2-y^2}$ } e⊖ on the axis

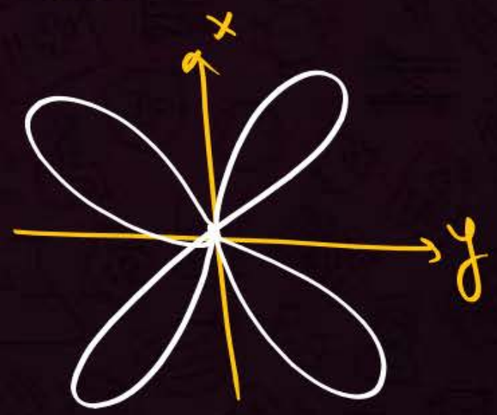
d_{xy}, d_{yz}, d_{zx} } e⊖ is in b/w the axis.

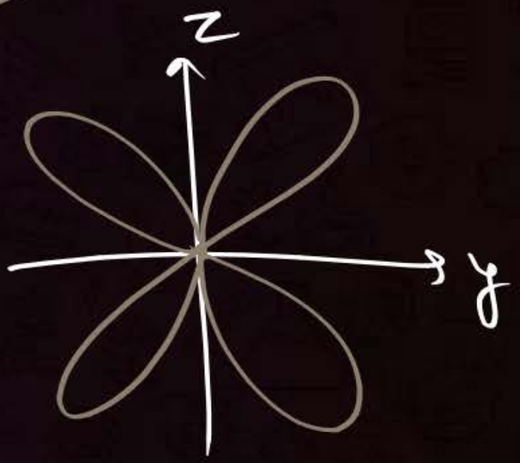
	m
d_{z^2} →	0
d_{zx} / d_{yz} →	±1
$d_{x^2-y^2}$ / d_{xy} →	±2



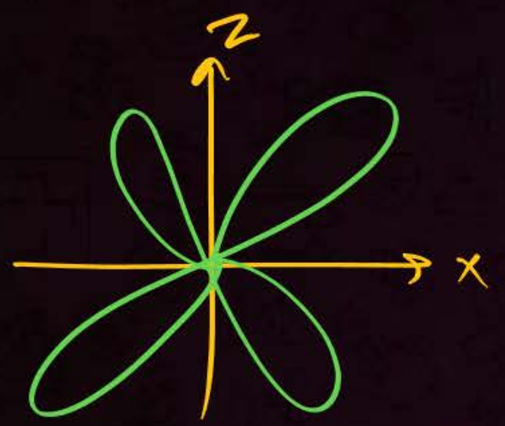
equal energy = degenerate orbitals.

d_{xy} → 2 nodal plane ← d_{yz}

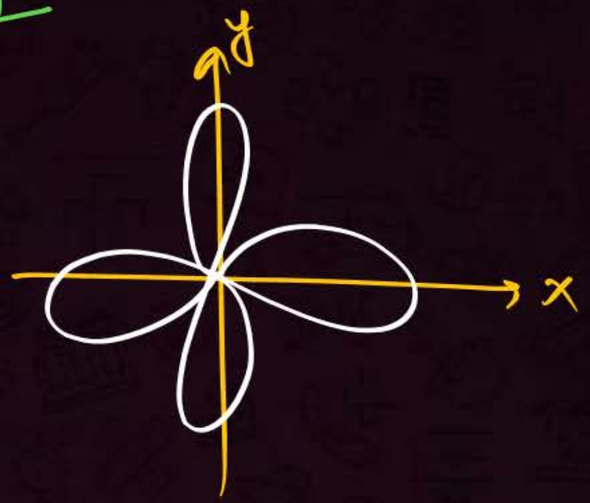




d_{xz} → 2 nodal plane

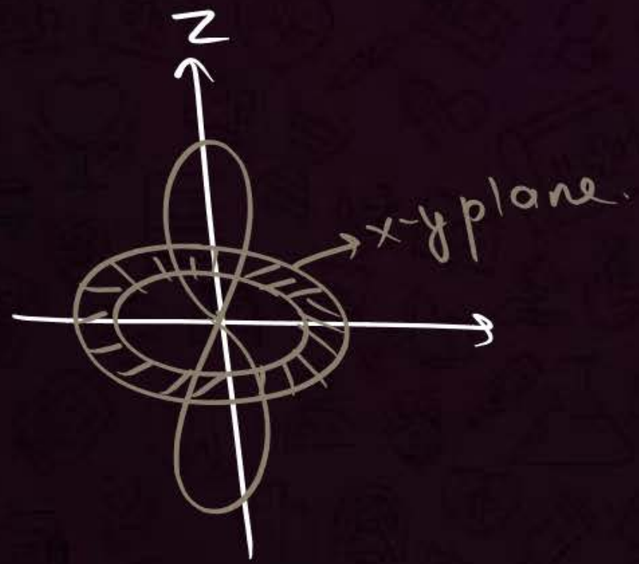


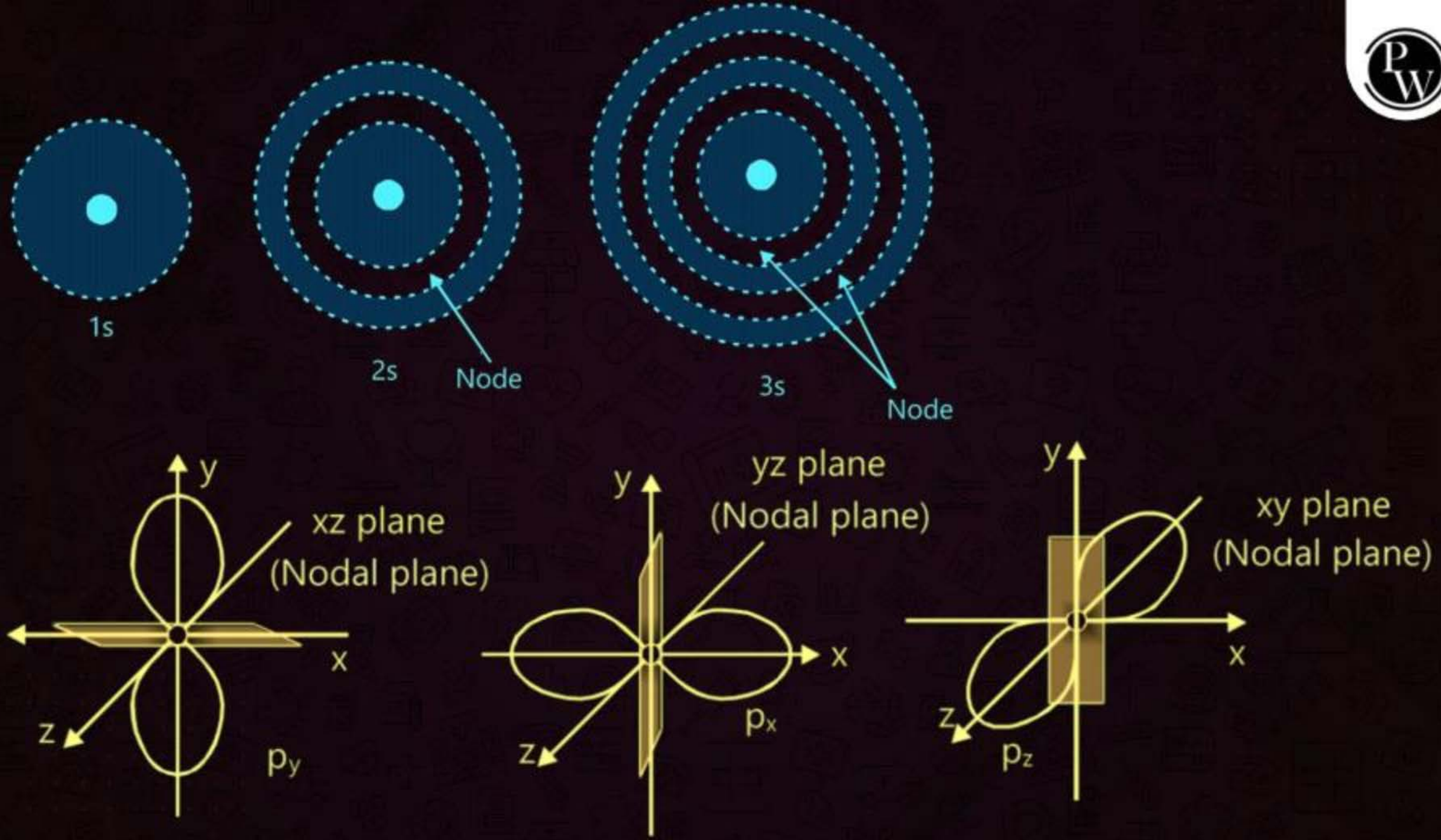
$d_{x^2-y^2}$ → 2 nodal plane.

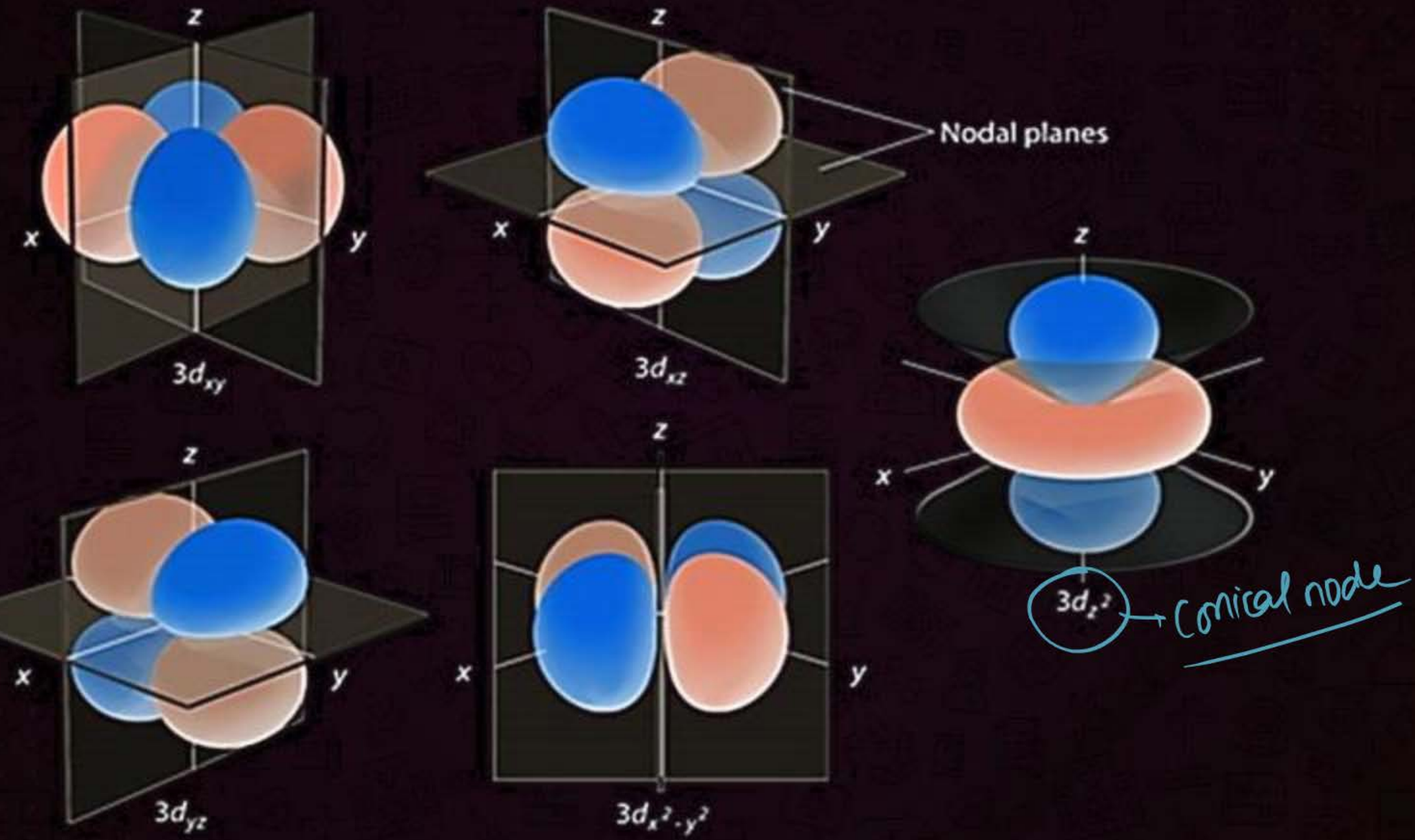


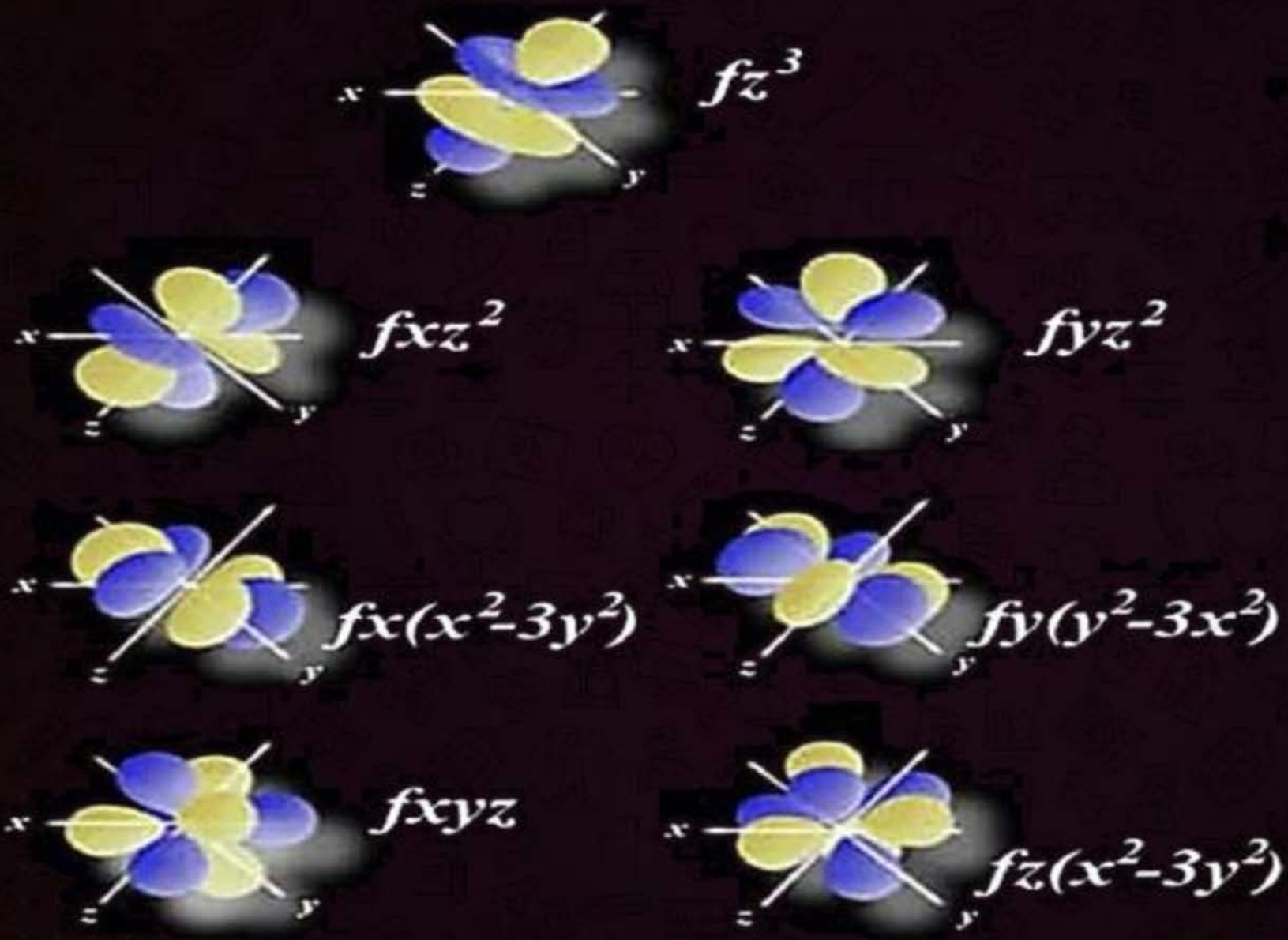
d_{z^2} →

no nodal plane




1s
2s
Node
3s
Node
y
xz plane
(Nodal plane)
x
z
p_y
y
yz plane
(Nodal plane)
x
z
p_x
y
xy plane
(Nodal plane)
x
z
p_z


z
x
y
$3d_{xy}$
z
x
y
Nodal planes
$3d_{xz}$
z
x
y
$3d_{z^2}$
Conical node
z
x
y
$3d_{yz}$
z
x
y
$3d_{x^2-y^2}$



f orbitals orientations

Applications of Quantum Numbers

① electronic configuration ⇒ arrangement of $e^{\ominus}$ in stable way around nucleus in different orbits/subshells

$e^{\ominus}$ are arranged/filled from lower energy subshell to higher energy subshell in increasing order.

(n+l) rule / Bohr-Bury rule

$H \rightarrow 1e^{\ominus} \rightarrow 1s^1$

$He \rightarrow 2e^{\ominus} \rightarrow 1s^2$

$Li \rightarrow 3e^{\ominus} \rightarrow 1s^2 2s^1$

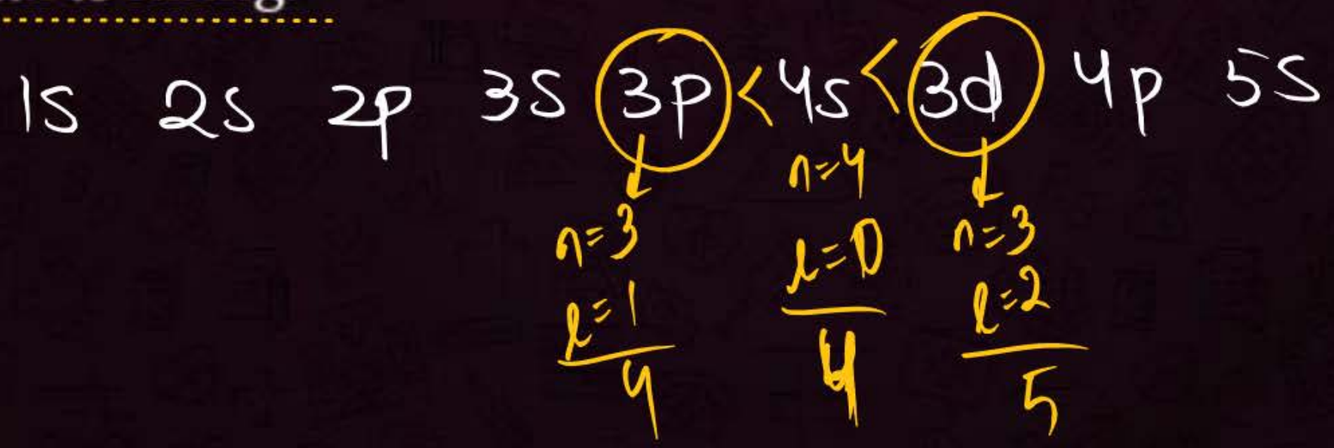
$Be \rightarrow 4e^{\ominus} \rightarrow 1s^2 2s^2$

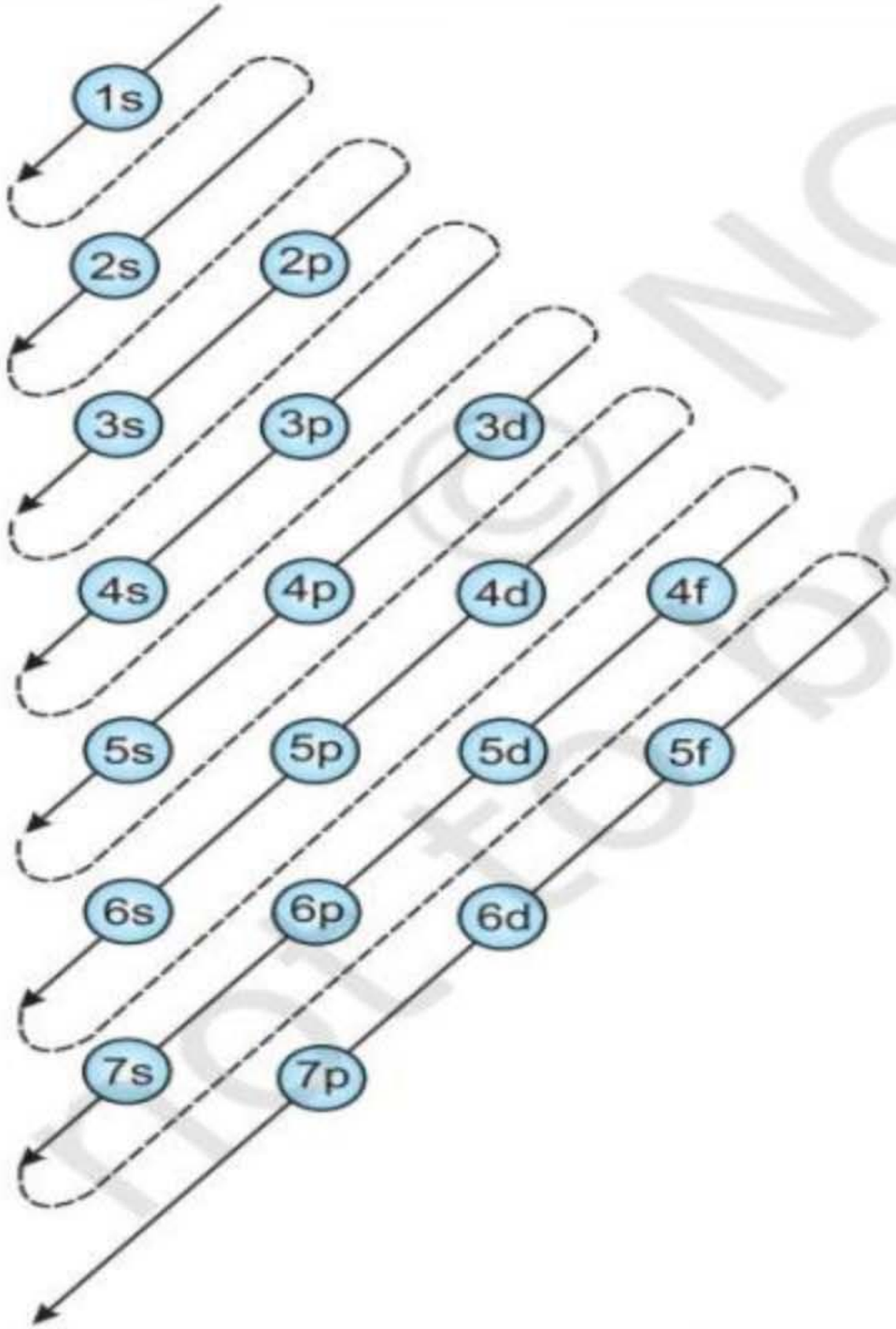
$B \rightarrow 5e^{\ominus} \rightarrow 1s^2 2s^2 2p^1$

Aufbau's Principle

Aufbau is a German word and its meaning is 'Building up'

- Aufbau principle gives a sequence in which various subshell are filled up depending on the relative order of the energies of various subshell.
- **Principle:** The subshell with minimum energy is filled up first when this subshell obtained maximum quota of electrons then the next subshell of higher energy starts filling.





Shortcut

1s 2s 2p 3s 3p 4s

3d 4p 5s 4d 5p 6s

4f 5d 6p 7s 5f 6d 7p 8s

$Z = 115 \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^6\ 7s^2\ 5f^{14}\ 6d^{10}\ 7p^3$

$Z = 51 \Rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^3$

electronic configurations of Ions

$Fe \rightarrow 26 \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

$Fe^{+2} \rightarrow 24 \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^0$

$Fe^{+3} \rightarrow 23 \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^0$

$e^{\ominus}$ removal takes place from outer orbit / outer subshell

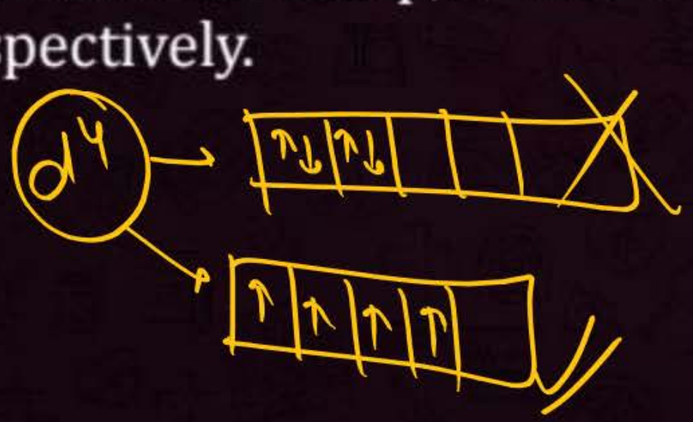
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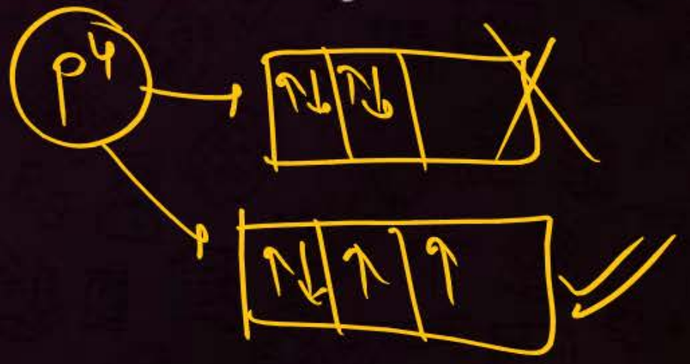
$Mn \rightarrow 25 \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$

$Mn^{+2} \rightarrow 23 \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^0$

Hund's Rule of Maximum Multiplicity

- This rule deals with the filling of electrons into the orbitals belonging to the same subshell (that is, orbitals of equal energy, called degenerate orbitals).
- It states: pairing of electrons in the orbitals belonging to the same subshell (p, d or f) does not take place until each orbital belonging to that subshell has got one electron each i.e., it is singly occupied.
- Since there are three p, five d and seven f orbitals, therefore, the pairing of electrons will start in the p, d and f orbitals with the entry of 4^{th}, 6^{th} and 8^{th} electron, respectively.

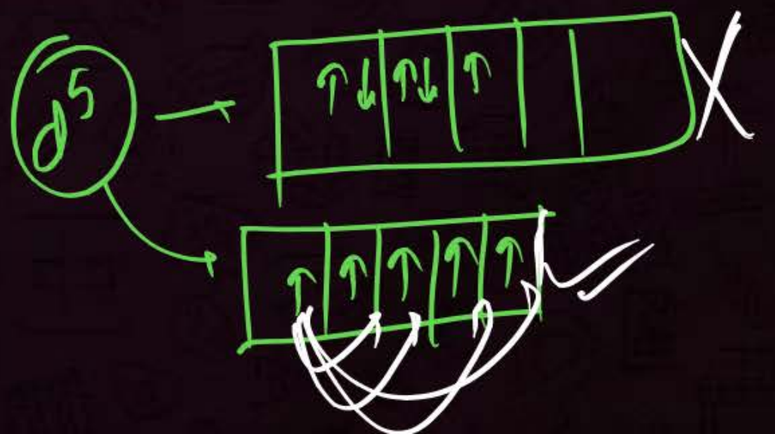




Stability of Completely Filled and Half Filled Subshells

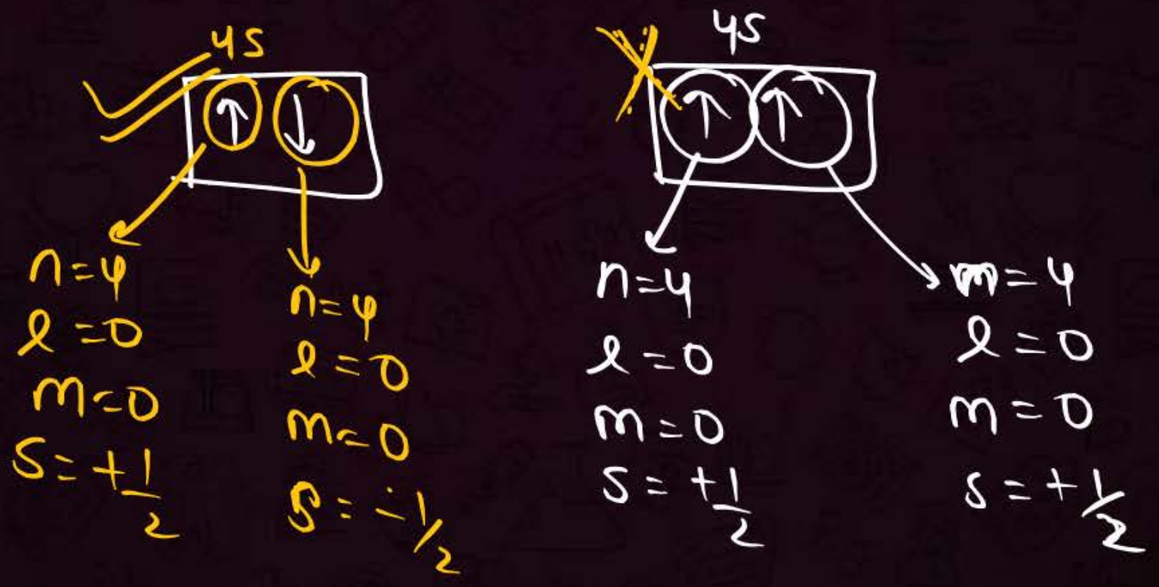
The completely filled and exactly half filled sub shells are stable due to the following reason.

1. **Symmetrical Distribution of Electrons:** According to this, symmetry leads to stability, the completely filled or half filled subshells have symmetrical distribution of electrons in them and they are therefore more stable.
2. **Exchange Energy:** The number of exchanges which can take place is maximum when the subshell is either half filled or completely filled. As a result, the exchange energy is maximum and so is the stability.



Pauli's Exclusion Principle

In 1925, Pauli stated that no two electron in an atom can have same values of all four quantum numbers i.e., an orbital can accomodate maximum 2 electrons with opposite spin.



Magnetic Nature

magnetic moment (μ) = $\sqrt{n(n+2)}$ BM

BM = Bohr's magneton

where n = no. of unpaired $e^{\ominus}$

Paramagnetic

↓

weakly attracted towards magnetic field.

→ atleast one unpaired $e^{\ominus}$ is present

$B \Rightarrow 1s^2 2s^2 2p^1$



Paramagnetic

Diamagnetic ⇒ weakly repelled from magnetic field.

→ all $e^{\ominus}$ are paired.

$Be \rightarrow 1s^2 2s^2$



→ Diamagnetic

exceptions of E.C

Cr → 24 → $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$

→ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$ → more stable

Cu → 29 → $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$

→ $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$ more stable

QUESTION

The calculated spin only magnetic moment of Cr^{2+} ion is

A) 3.87 BM

B) 4.90 BM

C) 5.92 BM

D) 2.84 BM

$Cr \rightarrow 24 \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$

$Cr^{+2} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^4$



magnetic moment $= \sqrt{4(4+2)}$ BM

$= \sqrt{24}$ BM

QUESTION

Identify the correct order of increase in the energy of the orbitals for hydrogen atom

A $1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f$

B $1s > 2s = 2p > 3s = 3p = 3d > 4s = 4p = 4d = 4f$

C $1s = 2s = 3s = 4s > 2p = 3p = 4p > 3d = 4d > 4f$

D $1s = 2s = 3s = 4s < 2p = 3p = 4p < 3d = 4d < 4f$

QUESTION

The atomic numbers of elements X, Y and Z are 19, 21 and 25 respectively. The number of electrons present in the M-shell of these elements follow the order

(A) Z > X > Y

(B) X > Y > Z

(C) Z > Y > X

(D) Y > Z > X

M-shell → $n=3$

$X \to 19 \to 1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

$\hookrightarrow 2, 8, 8, 1$

$Y \to 21 \to 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$

$\hookrightarrow 2, 8, 9, 2$

$Z \to 25 \to 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$

$\hookrightarrow 2, 8, 13, 2$

QUESTION

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$

The number of d-electrons in Fe^{2+} (Z – 26) is not equal to the number of electrons in which one of the following?

(A) s-electrons in Mg(Z = 12) → $1s^2 2s^2 2p^6 3s^2$

(B) p-electrons in Cl(Z = 17) → $1s^2 2s^2 2p^6 3s^2 3p^5$

(C) d-electrons in Fe(Z = 26)

(D) p-electrons in Ne(Z = 10)

QUESTION

The number of orbitals associated with quantum numbers $n = 5, m_s = +\frac{1}{2}$

[JEE Main 2020]

(A) 25

(B) 50

(C) 15

(D) 11

orbitals $\Rightarrow n^2 = 25$

max $e^{\ominus} = 2n^2 = 50$

QUESTION

Which of the following is responsible to rule out the existence of definite paths or trajectories of electrons?

A. Pauli's exclusion principle

B. Heisenberg's uncertainty principle

C. Hund's rule of maximum multiplicity

D. Aufbau principle

QUESTION

Which of the following sets of quantum numbers are correct?

	n	l	m_l		n	l	m_l
I.	1	1	+2	II.	2	1	+1
III.	3	2	–2	IV.	3	4	–2

The correct option is

(A) II and III

(B) I and II

(C) I and III

(D) III and IV

QUESTION

The pair of ions having same electronic configuration is

A Cr^{3+}, Fe^{3+}

$24-3=21$ $26-3=23$

B Fe^{3+}, Mn^{2+}

$26-3=23$ $25-2=23$

C Fe^{3+}, Co^{3+}

D Sc^{3+}, Cr^{3+}

QUESTION

How many electrons can fit in the orbital for which n = 3 and l = 1?

3p

A 2

B 6

C 10

D 14

QUESTION

Two electrons occupying the same orbital are distinguished by

A Magnetic quantum number



B Azimuthal quantum number

C Spin quantum number

D Principal quantum number

QUESTION

From the following pairs of ions which one is not an iso-electron pair?

A Mn^{2+}, Fe^{3+}

B Fe^{2+}, Mn^{2+}

24 23

C O^{2-}, F^{-}

10 10

D Na^{+}, Mg^{2+}

10 10

QUESTION

Calculate the value of n, ℓ and m for 5s orbital?

n = 5
ℓ = 0
m = 0

A. 5, 0, 0

B. 5, 0, +1

C. 5, 1, 0

D. 5, 2, 0

QUESTION

Which of the following set of quantum numbers is not possible?

(a) $n = 2, \ell = 1, m = 0, s = -\frac{1}{2}$

(b) $n = 3, \ell = 2, m = 0, s = -\frac{1}{2}$

(c) $n = 2, \ell = 3, m = -2, s = \pm\frac{1}{2}$

(d) $n = 4, \ell = 2, m = -3, s = \pm\frac{1}{2}$

A a

B b

C c & d

D c

QUESTION

If n = 3, then which value of 'ℓ' is correct:

A 0

B 1

C 2

D All of them

QUESTION

An electron is in one of 4d orbital. Which of the following orbital quantum number value is not possible

A) n = 4

B) $\ell = 1$

C) m = 1

D) m = 2

QUESTION

If $\ell = 3$ then type of subshell and number of orbital is

(A) 3p, 3

(B) 4f, 14

(C) 5f, 7

(D) 3d, 5

QUESTION

Spin angular momentum for electron

A $\sqrt{s(s+1)}\frac{h}{2\pi}$

B $\sqrt{2s(s+1)}\frac{h}{2\pi}$

C $\sqrt{s(s+2)}\frac{h}{2\pi}$

D None

QUESTION

What will be the orbital angular momentum of 3d orbital

(A) $\sqrt{8}.\frac{h}{2\pi}$

(B) $\sqrt{12}.\frac{h}{2\pi}$

(C) $\sqrt{3}\frac{h}{2\pi}$

(D) $\sqrt{6}.\frac{h}{2\pi}$

3d

$l = 2$

$\sqrt{2(2+1)}\,\frac{h}{2\pi}$

QUESTION

How many total nodes are there in 4p:

4 - 1 = 3

A 2

B 3

C 4

D 0

QUESTION

How many angular nodes are present in 3d:

A 0

B 1

C 2

D 3

QUESTION

Which of the following value of n, ℓ and m represents the $7P_y$ orbital?

A) 7, 0, +1

B) 7, 1, +2

C) 7, 1, +1

D) 7, 2, +1

$n = 7$

$\ell = 1$

$m = \pm 1$

QUESTION

The value of n, ℓ and m for $5dz^2$ orbital?

A) 5, 1, 0

B) 5, 3, +2

C) 5, 3, –2

D) 5, 2, 0

QUESTION

How many radial nodes are present in 3s:

A 3

B 0

C 2

D 1

3-0-1 = 2

QUESTION

In potassium the order of energy level for 19^{th} electron is:

(A) $3s > 3d$

(B) $4s < 3d$

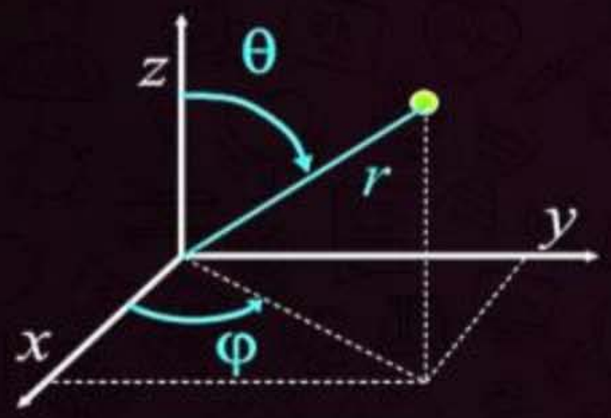
(C) $4s > 4p$

(D) $4s = 3d$

(K) $\rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d$

Spherical Polar Coordinates

Instead of Cartesian (x, y, z) the maths works out easier if we use a different coordinate system:



$x = r \sin\theta \cos\varphi$

$y = r \sin\theta \sin\varphi$

$z = r \cos\theta$

(takes advantage of the spherical symmetry of the system)

$\psi(x,y,z)$

$\psi(r,\theta,\phi)$

$$\text{let } a_0 = \frac{4\pi \epsilon_0 h^2}{\mu e^2} \approx 0.0529\text{nm}$$

$$\psi_{n,l,ml}$$

$$\downarrow$$

$$\psi_{1s} = \psi_{1,0,0} = \frac{1}{\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2} e^{-Zr/a_0}$$

$$\psi_{2s} = \psi_{2,0,0} = \frac{1}{4\sqrt{2\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(2 - \frac{Zr}{a_0}\right) e^{-Zr/2a_0}$$

$$\psi_{2p_z} = \psi_{2,1,0} = \frac{1}{4\sqrt{2\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(\frac{Zr}{a_0}\right) e^{-Zr/2a_0}\cos(\theta)$$

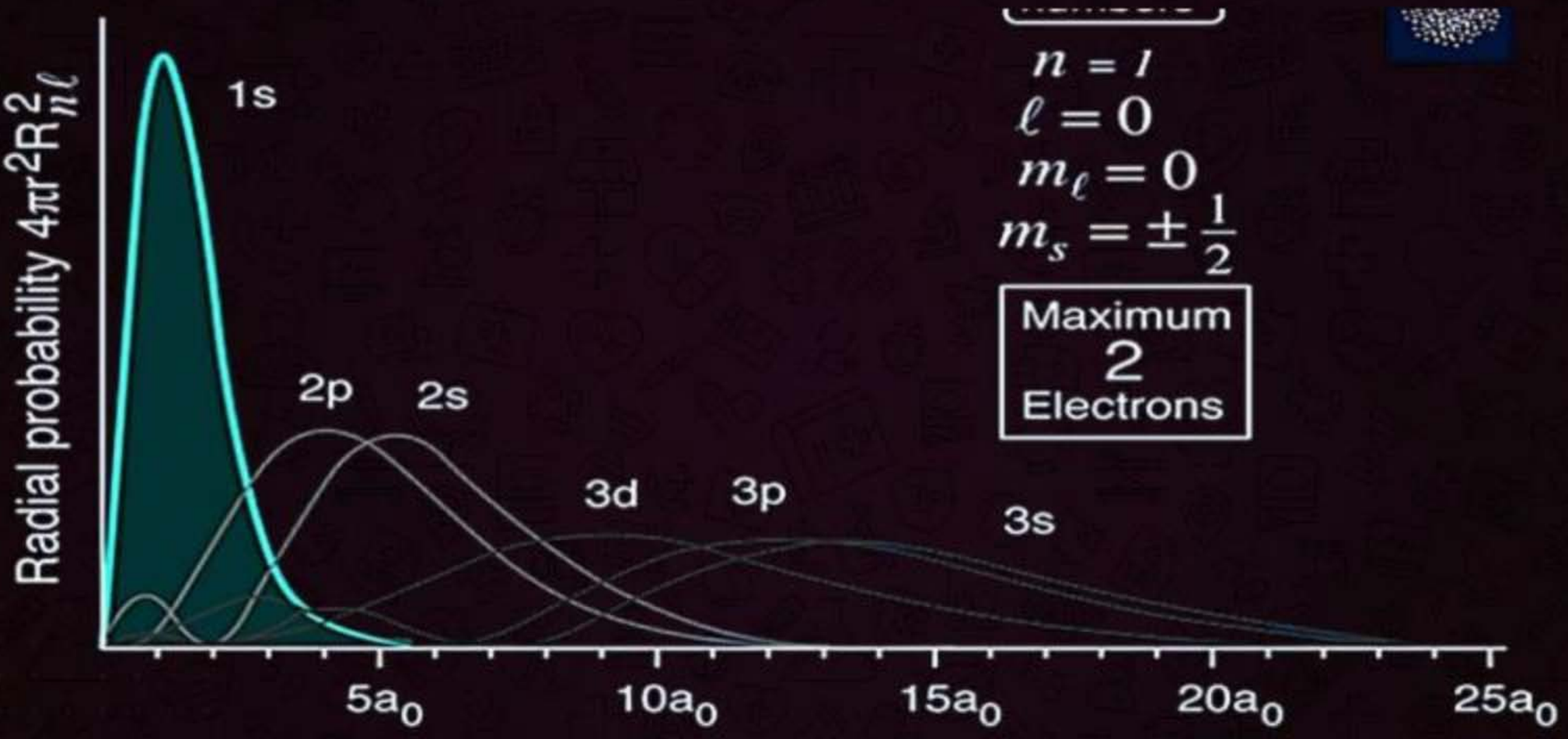
$$\psi_{2p_x/2p_y}\ \psi_{2,1,\pm1} = \frac{1}{8\sqrt{2\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(\frac{Zr}{a_0}\right) e^{-Zr/2a_0}\sin(\theta) e \pm i\varphi$$

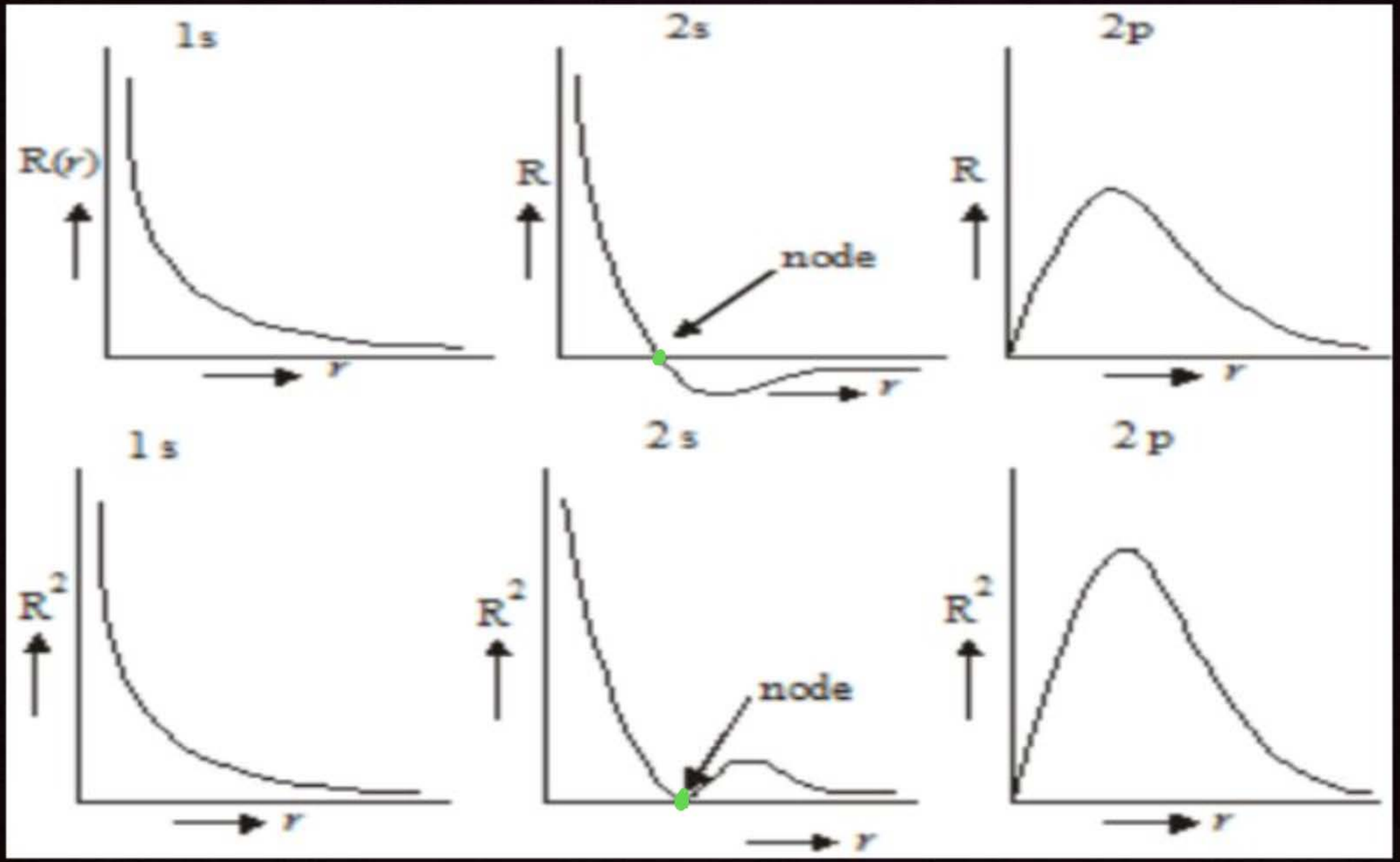
$$\psi_{2,0,0} = \frac{1}{81\sqrt{3\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(27 - 18\frac{Zr}{a_0} + 2\frac{Z^2r^2}{a_0^2}\right)e^{-Zr/3a_0}$$

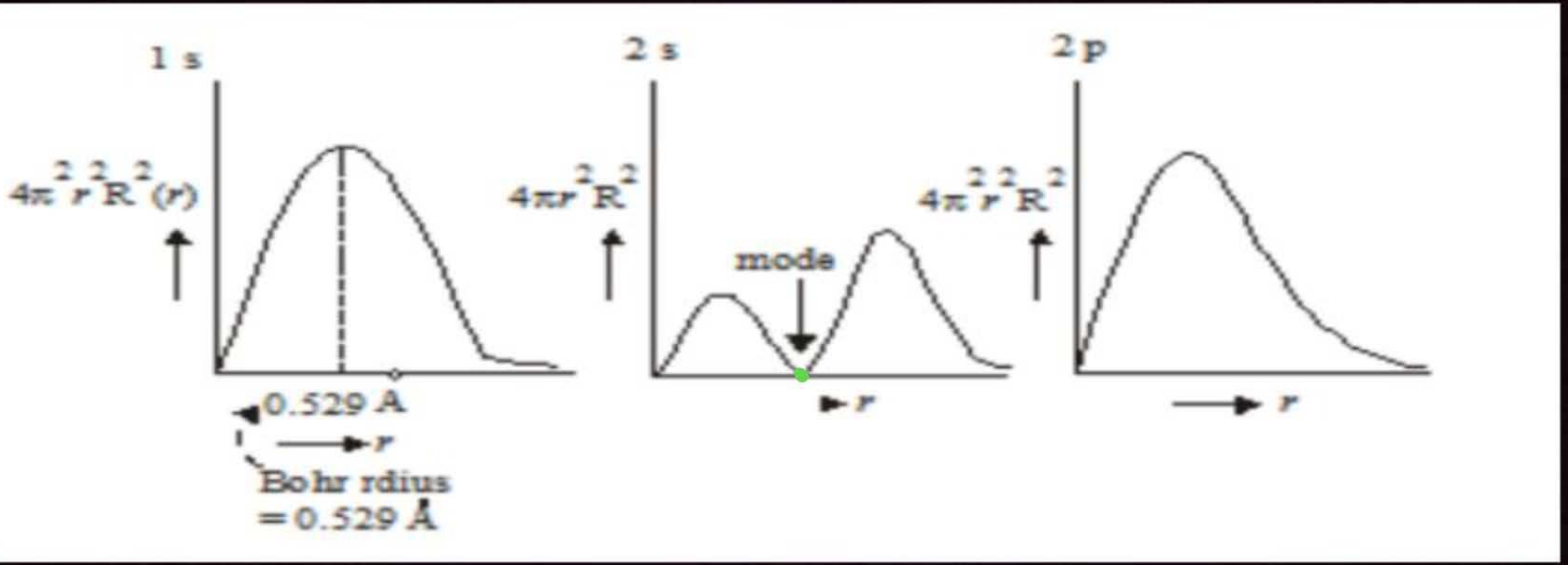
$$\psi_{3,1,0} = \frac{\sqrt{2}}{81\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(6 - \frac{Zr}{a_0}\right)\frac{Zr}{a_0}e^{-Zr/3a_0}\cos(\theta)$$

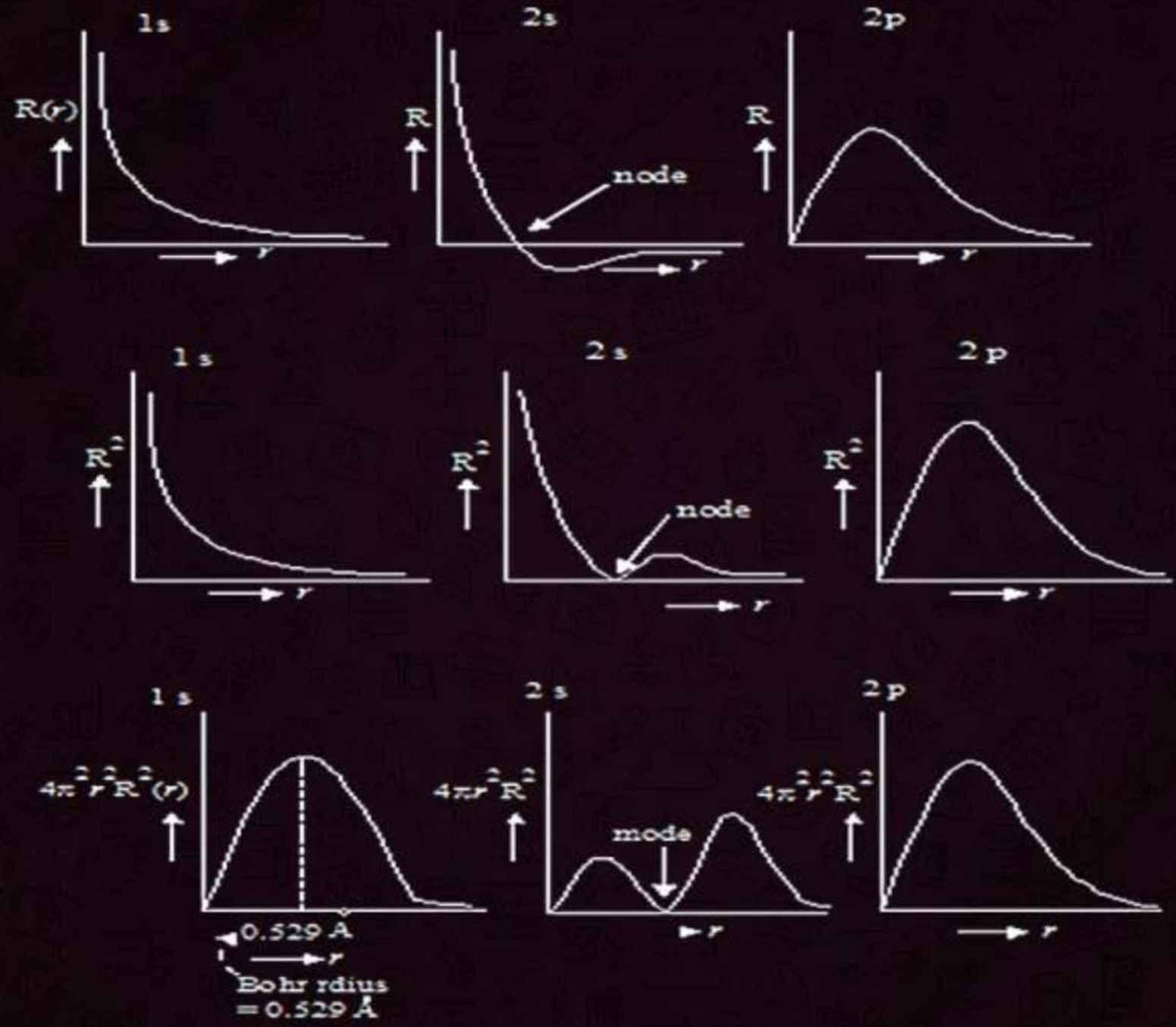
$$\psi_{3,1,\pm1} = \frac{1}{81\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\left(6 - \frac{Zr}{a_0}\right)\frac{Zr}{a_0}e^{-Zr/3a_0}\sin(\theta)e \pm i\varphi$$

$$\psi_{3,2,0} = \frac{1}{81\sqrt{6\pi}}\left(\frac{Z}{a_0}\right)^{3/2}\frac{Z^2r^2}{a_0^2}e^{-Zr/3a_0}(3\cos^2(\theta) - 1)$$

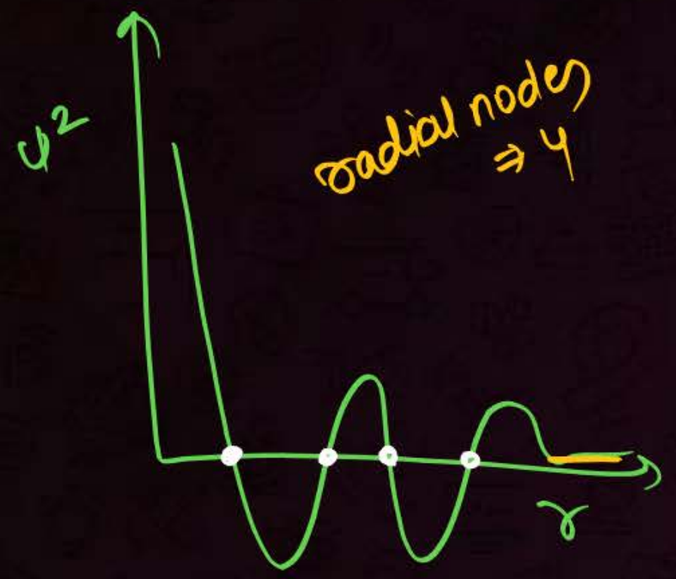

Radial probability $4\pi r^2 R^2_{n\ell}$
1s
2p
2s
3d
3p
3s
5a0
10a0
15a0
20a0
25a0
n = 1
ℓ = 0
$m_\ell = 0$
$m_s = \pm \frac{1}{2}$
Maximum
2
Electrons


1s
2s
2p
R(r)
R
node
r
1 s
2 s
2 p
R^2
node
r


1 s
$4\pi^2 r^2 R^2(r)$
0.529 Å
r
Bohr rdius
= 0.529 Å
2 s
$4\pi r^2 R^2$
mode
r
2 p
$4\pi^2 r^2 R^2$
r


1s
2s
2p
R(r)
R
node
r
1s
2s
2p
R²
node
r
1s
2s
2p
4π²r²R²(r)
4πr²R²
mode
0.529 Å
r
Bohr rdius
= 0.529 Å

Q



which of the following orbital is represented?

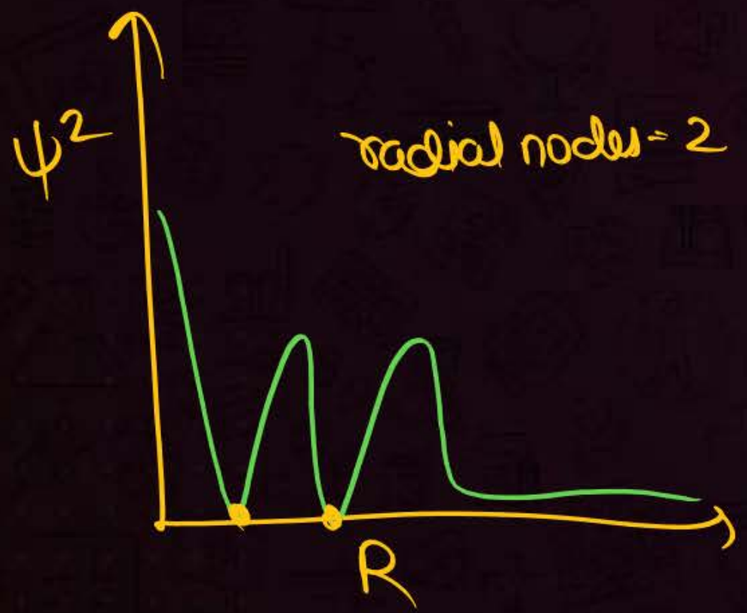
(a) 5s → 5-0-1 = 4

(b) 5p → 5-1-1 = 3

(c) 5d → 5-2-1 = 2

(d) 5f → 5-3-1 = 1

Q



Q. which of the following orbital is represented.

(a) 3p → 3-1-1 = 1

(b) 3s → 3-0-1 = 2

(c) 3d → 3-2-1 = 0

(d) None of them.

Summary

Atomic structure → Finished

FOR NOTES & DPP CHECK DESCRIPTION



Homework

- DPP
- PYQs

FOR NOTES & DPP CHECK DESCRIPTION


THANK YOU