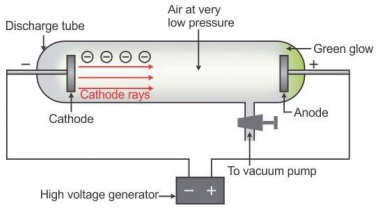
Atomic Structure

Fundamental Particle

	Mass	Relative Mass	Charge	Relative Charge
Electron	9.1×10^{-31} Kg	0	-1.6×10^{-19} C	−1
Proton	1.672×10^{-27} Kg	1	$+1.6 \times 10^{-19}$ C	+1
Neutron	1.674×10^{-27} Kg	1	zero	0

Discovery of electron



Production of cathode rays

Cathode Rays Discharge Tube

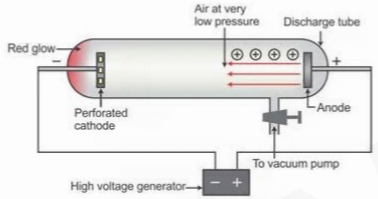
→ Cathode Rays are Fast moving electrons

→ Direction From Cathode to Anode

CATHODE RAYS

* Consist of -vely charged particles called electrons.
* They travel in straight line.
* Cathode ray posseses mass energy and penetration power
* When electric Field is applied, then they are deflected towards +ve side of Field.
* They produce X-rays when they strike heavy nucleus like tungsten, molybdenum.
* Specific charge or charge/mass or Ionic potential (e/m) of all cathode ray is same irrespective of gas present inside discharge tube.

ANODE RAY



Production of anode rays

Anode Rays Discharge Tube

→ Anode ray is fast moving +vely charged ion

→ Direction is From Anode to Cathode

ANODE RAY

* Consists of +vely charged ions
* They travel in straight line
* Anode ray posseses mass, energy and penetration power
* When electric field is applied, they are deflected towards -ve side of field.

Specific charge or $\frac{\text{charge}}{\text{mass}}$ $\left[\frac{e}{m}\right]$ ratio or Ionic potential is not same. It depends on gas inside discharge tube.

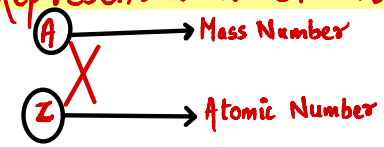
In Case of hydrogen, Anode rays are termed as PROTONS

NEUTRON → James Chadwick

$${}^{9}_{4}Be + {}^{4}_{2}He \longrightarrow {}^{12}_{6}C + {}^{1}_{0}n$$

neutron

Representation of Element



Mass Number (A) = No. of Proton + No. of Neutron

Atomic Number (Z) = No. of Proton

No of Neutron = A − Z

Types of Rays

α-Rays → Consists of α-Particles ($_2^4He^{++}$)

β-Rays → Consists of −vely charged particles similar to electrons

γ-Rays → Neutral electromagnetic radiations.

Penetration Power : γ > β > α

Ionisation Power: α > β > γ

NOTES:

Units of energy : J eV ergs

$1\ eV = 1.6 \times 10^{-19}\ J$ $1\ J = 10^{7}$ ergs

Units of length or distance : A° (Angstrom) nm (nanometer)

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

ISO-SERIES

Isotopes : same atomic number, different mass number

$_1^1H$ $_1^2H$ $_1^3H$

Isobars : same mass number, different atom number

$_{18}^{40}Ar$ $_{20}^{40}Ca$

Isotones : Having same number of neutrons (A−Z)

$_{19}^{39}K$ $_{20}^{40}Ca$

Iso-Electronic : Having same number of electrons.

CO (14e⁻) N_2 (14e⁻) CN^- (14e⁻)

Iso-Diaphers : Having same isotopic number (A−2Z)

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

Isosteres : Molecules having same number of atoms and same number of electrons eg. CO N_2

ATOMIC MODELS

1) JJ Thomson Model or Plum Pudding Model or Water Melon Model

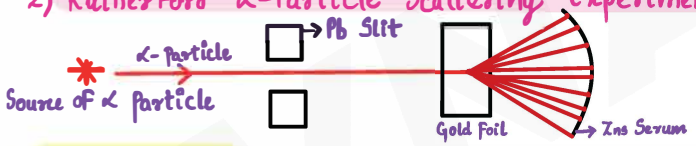


+ve is all around charge atom

electrons are embedded in between

Drawback: It could not explain Rutherford α-Particle Scattering Experiment.

2) Rutherford α-Particle Scattering Experiment



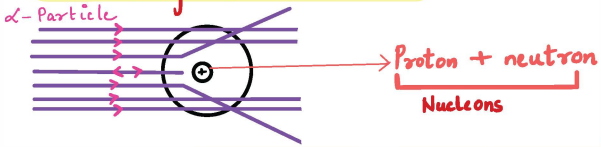
OBSERVATION

* Most of the α-Particle went straight.
* Few α-Particle were deflected by small angles.
* Very few α-Particle (1 in 20,000) deflected by 180°

CONCLUSION

* Most of the space inside atom is empty.
* A +vely charged sphere is present at center of atom called NUCLEUS

Rutherford Model



Results : 1) $R_{atom} = 10^{-10}\ m$ $R_{nucleus} = 10^{-15}\ m$

2) Radius of any Nucleus $R = R_0 (A)^{1/3}$ (A: Mass Number)

Limitations

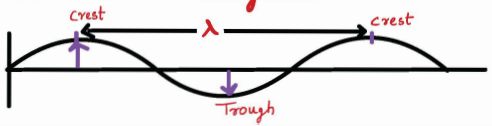
1) It could not explain internal distribution of electron.
2) It could not explain stability of atom.

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Dual Nature of Light

- Wave Nature
- Particle Nature

Wave Nature of Light



Wavelength (λ):- Distance b/w 2 consecutive crest or trough

Wave Number ($\bar{\nu}$):- Defined as no. of waves per unit of length

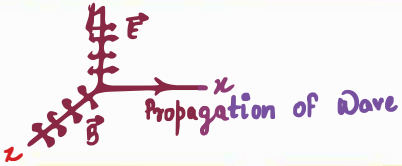
$$\bar{\nu} = 1/\lambda$$

Frequency (f):- No of waves passing through a particular point in 1 second. Unit = Hz or Per sec

Amplitude (A):- Height of crest or depth of trough

Velocity (v):- Distance travelled by wave per unit time Unit:- m/sec

Electromagnetic Waves



* Electric Field, Magnetic field and propagation of wave all $\perp^r$ to each other.
* Travel with speed of light $c = 3 \times 10^8$ m/s
* Can travel in vaccum. $c = f \times \lambda$

Electro-Magnetic Spectrum

Cosmic Rays < γ-Rays < X-Rays < UV Rays < Visible light < Infrared rays < Micro Waves < Radio Waves

Visible light: VIBGYOR

$\lambda \uparrow$

$f \downarrow$

Particle Nature of Light

Planck's Quantum Theory or Black Body Radiation

* Black Body is an ideal body which emits or absorbs radiation of all frequency.
* Radiations emitted or absorbed are in the form of small pockets or bundles of energy known as quanta or Photon

$E_p = hf$ Joules

$E_p = \frac{hc}{\lambda}$ Joules

h = Planck's constant = 6.626×10^{-34}

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

Photo-Electric Effect



Emissions of electrons from surface of metal by falling photon of suitable energy is known as photoelectric effect.

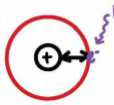
Work Function (ϕ):- Minimum energy required for Photoelectric effect. It is Fixed for a metal.

Threshold Frequency (f_0):- Minimum frequency required for Photoelectric effect.

Threshold Wavelength (λ_0):- Maximum wavelength required for Photoelectric effect.

Kinetic Energy of Ejected Electron

→ Based on Conservation of Energy.



$E_p = \phi + K.E$

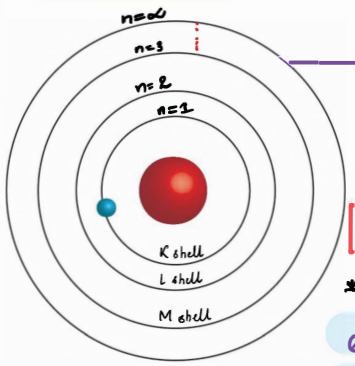
Notes:
- K.E of ejected electron does not depend on Intensity
- K.E of ejected electron depends on Frequency

: Photocurrent or no. of electron ejected depend on Intensity.

: Photocurrent or no. of electron ejected does not depend on Frequency.

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BOHR'S MODEL



→ There are infinite shells in an atom.

* Atom consists of 2 Parts:
  Proton + Neutron → Nucleus
* Extra nuclear Parts:
  e^- revolving in a Fixed circular orbit.

→ Angular momentum of electron is quantised

$$mvr = \frac{nh}{2\pi} \quad n = 1, 2, 3.$$

Notes:

* Ground state → n=1
* Excited state → shell other than n=1
* Energy of electron ↑, as we move away from nucleus
  $E_1 < E_2 < E_3 < \ldots < E_\infty$
* Energy difference b/w 2 consecutive shells decrease as we go away from nucleus.
  $E_2 - E_1 > E_3 - E_2 > E_4 - E_3 \ldots\ldots$

Note:
Bohr Model is applicable only for single electron species. eg. H, He^+, Li^{+2}, Be^{+3}

Formulas:

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

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

$$\text{Total Energy} = -13.6 \frac{Z^2}{n^2}\ eV = -2.18 \times 10^{-18} \frac{Z^2}{n^2}\ J$$

* Energy of Infinite shell: $E_\infty = 0$

* Ratio of KE, PE and TE:
  KE : PE : TE ≡ 1 : 2 : -1

Energy Difference b/w 2 Shells :-



$$\Delta E = 13.6\ Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) eV$$

* Hydrogen Spectrum

$$\frac{1}{\lambda} = R_H Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

R_H = Rhydberg's Constant = $1.1 \times 10^7\ m^{-1}$

Ionisation Energy

Ground state (n=1) → Infinity shell (n=∞)
Ionisation Energy

$$I.E = 13.6\ Z^2$$

Hydrogen Spectrum

Hydrogen spectrum is :
i) Discontinous ii) Line iii) Emission $n_2 \longrightarrow n_1$

n_1 → lower Orbit
n_2 → Higher Orbit

Series	n_1 (Lower orbit)	n_2 [Higher orbit]	Region
Lyman	1	2, 3, 4, 5 ... ∞	Ultraviolet Region
Balmer	2	3, 4, 5, 6 ... ∞	Visible
Paschen	3	4, 5, 6, 7 ... ∞	Infrared
Bracket	4	5, 6, 7 ... ∞	Infrared
Pfund	5	6, 7, ... ∞	Infrared
Humphery	6	7, 8, ... ∞	Infrared

Formula : $\frac{1}{\lambda} = R_H Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

n_1 : lower orbit n_2 : Higher orbit
R_H : Rydhberg's Constant = $1.1 \times 10^7\ m^{-1}$

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Dual Nature of Matter [De-Broglie Hypothesis]

$\lambda \propto \frac{1}{p}$ → De-Broglie Wavelength OR Matter Waves

$\lambda = \frac{h}{p}$ | $\lambda = \frac{h}{\sqrt{2mKE}}$ | $\lambda = \frac{h}{mv}$ | $\lambda = \sqrt{\frac{150}{V}}\ A^\circ$

HEISENBERG'S UNCERTAINITY PRINCIPLE [HUP]

According to HUP, it is impossible to determine exact position and momentum of electron around the nucleus simultaneously with accuracy.

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

Δx : Uncertainity in Position

Δp : Uncertainity in Momentum.

Limitations OF BOHR Model :-

: Applicable on single electron species.

: Could not explain De-Broglie Hypothesis and HUP

: Could not explain splitting of spectral lines in presence of magnetic field (Zeeman EFFECT) and Electric Field (STARK EFFECT)

Wave Mechanical Model of Atoms

→ Developed by Schrodinger

→ Schrondiger assumed electron to be wave.

SCHRODINGER WAVE EQUATION

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

Quantum Numbers

- Set of 4 numbers which tell us about energy of electron, subshell, orientation and spin of electron.
  1) Principal QN
  2) Azimuthal QN
  3) Magnetic QN
  4) Spin QN

PRINCIPAL QN :-

* Represented by n
* Tells about SHELL/ORBIT
* Gives idea about energy, radius and velocity of electrons.
* Max number of electrons in shell is given by $2n^2$ eg. n=1 K shell Max $e^- = 2(1)^2 = 2$
* Orbit Angular Momentum : $mvr = \frac{nh}{2\pi}$

AZIMUTHAL QN / Subsidiary Quantum Number

* Represented by l
* Tells about Subshell.
* Values of l

		SHAPES
l=0	s-subshell	spherical
l=1	p-subshell	Dumb bell
l=2	d-subshell	double Dumbbell
l=3	f-subshell	COMPLEX

* For a given value of 'n', 'l' have values from 0 to (n-1)
* Orbital Angular Momentum: $\sqrt{l(l+1)}\frac{h}{2\pi}$

MAGNETIC QN :

* Represented by 'm'
* Tell us about number and orientation of orbitals.
* Number of orbitals in shell is given by n^2
* Value of 'm' depends on value of l and for a given value of l, m have values ranging from $-l$ to l.

SPIN QN

* Represented by s.
* Can have only two values $s = +1/2$ or $s = -1/2$

CLOCKWISE SPIN UP (↑) — $s = +1/2$; ANTI-CLOCKWISE SPIN DOWN (↓) — $s = -1/2$

* An orbital can accomodate max 2 electrons of opposite spin ↑↓

ENERGY OF ELECTRON

Case I : Single electron species H, He^+, Li^{+2}, Be^{+3}

* Energy depends only on (n)
* Lower the value of n, Lower is the energy.

Case 2 : Multi electron species

* Energy depends on (n+l)
* Lower the value of (n+l), lower is the energy.
* If (n+l) is same, then lower the value of n lower is energy

For eg. 1s 2s 2P 3s 3P 4s 3d

1s < 2s < 2P < 3s < 3P < 4s < 3d

ELECTRONIC CONFIGURATION

1) **AUFBAU RULE**

Electrons are filled in increasing order of energy. 1s < 2s < 2P < 3s < 3P < 4s < 3d

2) **PAULI'S EXCLUSION PRINCIPLE**

No two electrons can have same value of all four quantum numbers

3) **HUND'S RULE OF MAXIMUM MULTIPLICITY**

Pairing of electrons is done only when each orbital contains one electron of same pair.

NOTE :

Diamagnetic : zero unpaired electron

For eg. $Z = 10 \rightarrow Ne = [He]\ 2s^2\ 2p^6$ — 1↓ | 1↓ | 1↓ | 1↓

Paramagnetic : Having atleast one unpaired electron.

For eg. $Z = 21 \rightarrow Sc = [Ar]\ 4s^2\ 3d^1$ — 1 | | | |

Magnetic Moment (u) : $\sqrt{n(n+2)}$ BM (n → unpaired e^-)

Reason For Half Filled and Fully-Filled Stability

i) Symmetrical distribution of e^-.

ii) Exchange Energy : More Exchange Energy → More Stability

NODES

ψ → Wave Function ; ψ^2 → Probability of e^-

Region of space where probability of finding an e^- is zero $\psi^2 = 0$

Radial Node = $n-l-1$

Angular Node = l

Total Node = $n-1$

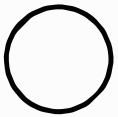
Nodal Plane (l) = l

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SHAPES OF ORBITALS

1] s- orbital

Shape : Spherical



2) p- orbital

Shape : Dumb - bell



NP = yz



NP = xz



NP = xy

3) d - Orbital

Shape : Double Dumb bell

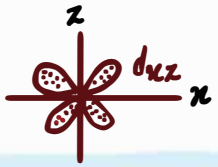
d - orbital

- Non - Axial (3 orbital) : d_{xy} d_{yz} d_{zx}
- Axial (2 orbital) : $d_{x^2-y^2}$ d_{z^2}

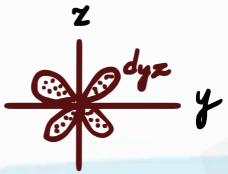
Non - Axial



NP = zx, zy

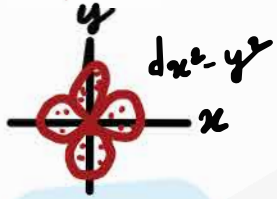


NP = yx, yz

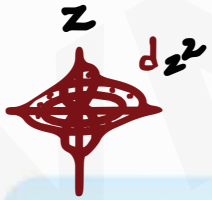


NP = xy, xz

Axial



NP = 2



NP = 0

NOTE

No of Waves = Orbit Number

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

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