

- * Distance of closest approach: It is the distance from which the nucleus of an atom, the α -particle comes to rest and its kinetic energy is totally converted into Electrostatic Potential Energy. It is denoted by r_0
 $\Rightarrow r_0 = \frac{1}{4\pi\epsilon_0} \frac{2Ze^2}{\frac{1}{2}mv^2}$
- * Atomic number (Z) of gold atom $\Rightarrow Z = 79$
- * Diameter of atom $- 10^{-10} \text{ m}$
- * Radius of atom $- 10^{-11} \text{ m}$
- * Diameter of nucleus $- 10^{-14} \text{ m}$
- * Impact Parameter (b) $= \frac{1}{4\pi\epsilon_0} \frac{Ze^2 \cot \frac{\theta}{2}}{\frac{1}{2}mv^2}$
- * Impact Parameter (b) is inversely proportional to the angle of scattering (θ) $\Rightarrow b \propto \frac{1}{\theta}$
- * the equation $mvr = n \frac{h}{2\pi}$ is called "Bohr's Quantisation condition".
- * the equation $h\nu = E_i - E_f$ is called Bohr's Frequency condition.
- * Bohr's radius $\Rightarrow r = \frac{n^2 h^2 \epsilon_0}{\pi m e^2}$
- * velocity of electron $\Rightarrow v = \frac{1}{4\pi\epsilon_0} \cdot \frac{2\pi e^2}{nh} = \frac{e^2}{2nh\epsilon_0}$
- * If ' c ' is velocity of light $\Rightarrow v = \left(\frac{1}{4\pi\epsilon_0} \cdot \frac{2\pi e^2}{ch} \right) \frac{c}{n}$
- * the factor $\frac{1}{4\pi\epsilon_0} \cdot \frac{2\pi e^2}{ch}$ is called fine structure constant. It is denoted by α .
- * the value of $\alpha = \frac{1}{137}$ $\Rightarrow v = \frac{1}{137} \frac{c}{n}$

$$\cot \frac{\theta}{2} = \tan \phi$$

$\theta \rightarrow$ scattering angle.
 $\phi \rightarrow$ deflection "

$u \rightarrow$ velocity of α -particle

$$\tan \phi = \frac{2b}{r_0} \quad \tan \phi = \frac{2b}{r}$$

Energy of electron: $E_n = - \left(\frac{1}{4\pi\epsilon_0} \right)^2 \cdot \frac{2\pi^2 m e^4}{n^2 h^2}$

Energy Quantisation: $E_1 = - \left(\frac{1}{4\pi\epsilon_0} \right)^2 \cdot \frac{2\pi^2 m e^4}{n^2 h^2}$

i.e. $E_n = \frac{-13.6}{n^2} \text{ eV}$
 $E \propto \frac{1}{n^2}$

$E_2 = \frac{1}{4} E_1$

$E_3 = \frac{1}{9} E_1$

$E_\infty = 0$

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

An electron can have only some definite values of energy while revolving in the orbits $n=1, 2, 3, \dots$. It is called Energy Quantisation.

Rydberg's constant for Hydrogen (R_H) $\rightarrow \left(\frac{1}{4\pi\epsilon_0} \right)^2 \frac{2\pi^2 m e^4}{c h^3}$

Its value is $1.09678 \times 10^7 \text{ m}^{-1}$

$R_H = \frac{m e^4}{8 \epsilon_0^2 h^3 c}$

charge of electron, $e = 1.6 \times 10^{-19} \text{ C}$ ✓

velocity of light, $c = 3 \times 10^8 \text{ m s}^{-1}$ ✓

Planck's constant, $h = 6.62 \times 10^{-34} \text{ J s}$ ✓

value of $\frac{1}{4\pi\epsilon_0}$ is $9 \times 10^9 \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$

charge (e) of the electron is measured by Millikan's oil drop method ✓

The ratio of charge to mass (e/m) for an electron is measured by "Thomson".

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mass of Electron (m) = 9.1×10^{-31} kg

mass of Proton is 1835 times of mass of electron.

Avogadro's number (N) = 6.023×10^{23} N/C 1 Farad = 96500 coulomb

Cathode rays or positive rays are discovered by "E. Goldstein".
Wien observed that these rays can be deflected in magnetic field and hence they are called positive rays.

$$1 \text{ a.m.u} = 1.66 \times 10^{-27} \text{ kg}$$

$$1 \text{ kilowatt hour} = 3.6 \times 10^6 \text{ Joules}$$

Mass energy equivalence, $E = mc^2 \Rightarrow E = 931 \text{ MeV}$.

Orbital Frequency of electron is $\frac{1}{T} = \frac{v}{2\pi r}$

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

the ionization potential (or) ionization energy of an hydrogen atom is 13.6 eV. Ionization potential 13.6 V.

the excitation energy required by the electron to excite from state n_1 to state n_2 is $E_{n_2} - E_{n_1}$

$$\text{ex: from state 1 to state 4} \Rightarrow E_4 - E_1 = 13.6 - 0.85 = 12.75 \text{ eV}$$

When the hydrogen atom is subjected to external energy the electron jumps from lower energy level to higher energy level i.e. it gets excited.

The excited state is not stable, hence the electron returns to the ground state in about 10^{-8} seconds.

$$\bar{\nu} = \frac{1}{\lambda} = R \cdot \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

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Spectral series of hydrogen atom:

- Lyman series lie in ultraviolet region. ✓
- Balmer series ^{lies} ~~lies~~ in near ultraviolet region and visible region.
- Paschen series lie in infra-red region.
- Brackett series also lies in infra-red region.
- Pfund series also lies in far infra-red region.

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$$\frac{1}{\lambda} = R \left[\frac{1}{n_f^2} - \frac{1}{n_i^2} \right]$$

S.NO	Series observed	value of n_f	value of n_i	Position in the spectrum
1.	Lyman series	1	2, 3, 4, ... ∞	ultraviolet
2.	Balmer series	2	3, 4, 5, ... ∞	visible
3.	Paschen series	3	4, 5, 6, ... ∞	Infrared
4.	Brackett series	4	5, 6, 7, ... ∞	Infrared
5.	Pfund series	5	6, 7, 8, ... ∞	far Infrared

Note:- corresponding to the jump of electrons from some higher energy state to the lower energy state corresponding to $n_f = 6$ another spectral series known as Humphrey series results.

thus, the wavelength of the spectral lines in the Humphrey series are given by $\frac{1}{\lambda} = R_H \left(\frac{1}{6^2} - \frac{1}{n_i^2} \right)$
 where $n_i = 7, 8, \dots$. this series lies in the far infra-red region.

vip
vise Velocity of an electron is independent of its mass. ✓

Velocity of an electron is inversely proportional to the orbit i.e. $V \propto \frac{1}{n}$

vise The electron in the inner most orbit has highest velocity.

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Velocity of an electron is independent of its mass. ✓

Velocity of an electron is inversely proportional to the orbit i.e. $V \propto \frac{1}{n}$

The electron in the inner most orbit has highest velocity.

Orbital frequency is inversely proportional to the cube of 'n'. $\Rightarrow \frac{1}{T} \propto \frac{1}{n^3}$

Radii of orbits increase with 'n'. ✓

not $\frac{1}{n^3}$

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If E_p & E_k represents potential & kinetic energies of the orbital electron, then $E_k = -E_p/2$ ✓

When a hydrogen atom is raised from the ground state to an excited state both K_E and P_E decrease. $[E \propto \frac{1}{n^2}]$

The energy difference between two consecutive energy levels decreases as the quantum number 'n' increases.

When a hydrogen atom is bombarded, the atom is excited to the $n=4$ state of hydrogen atom. The energy released, when the atom falls from $n=4$ state to

ground state is 12.75 eV

Soln- $E_1 = -13.6 \text{ eV}$ $E_4 = \frac{1}{16} \times -13.6 \text{ eV} = -0.85 \text{ eV}$

$E_4 - E_1 = 12.75 \text{ eV}$ ✓

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* To explain his theory Bohr used "conservation of angular momentum". [VVS]

* According to Bohr's Principle, the relation between Principal Quantum number (n) and radius of orbit is $\boxed{r \propto n^2}$

* When the hydrogen atom is in first excited level, its radius is four times that of radius of 1st orbit.

* In terms of the Bohr's radius a_0 , the radius of the second Bohr orbit of a hydrogen atom is given by $4a_0$

Solⁿ

$$a_0 = \frac{n^2 h^2 \epsilon_0}{\pi m e^2}$$

$$n=1 \Rightarrow a_0 = \frac{h^2 \epsilon_0}{\pi m e^2}$$

$$n=2 \Rightarrow a_0 = 4 \left(\frac{h^2 \epsilon_0}{\pi m e^2} \right) = 4a_0$$

4) the velocity of an electron in ground state is

$$\frac{e^2}{2h\epsilon_0} = \underline{2 \times 10^6 \text{ m/sec}}$$

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* The energy of a hydrogen atom in its ground state is -13.6 eV . The energy of the level corresponding to quantum number $n=5$ is -0.54 eV .

Soln

$$E_5 = \frac{1}{25} E_1 = \frac{1}{25} \times -13.6 = -0.54\text{ eV}$$

* The ionization energy of hydrogen atom is 13.6 eV . Following Bohr's theory the energy corresponding to a transition between 3^{rd} and 4^{th} orbit is 0.66 eV .

* The ground state energy of H-atom is -13.6 eV . The energy needed to ionise H-atom from its second excited state is 1.51 eV .

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Let ' t ' and ' n ' be thickness and no. of atoms per unit volume of scatterer respectively. Let ' Q ' be total no. of α -particles that strike unit area of scatterer. It should be noted that any α -particle whose initial velocity would bring it within a distance ' b ' of nucleus will be deflected through an angle ' θ '.

To determine probability that an α -particle would come within this distance, we imagine a circle of radius ' b ' drawn around each nucleus. The area occupied by all such circles in unit area of foil is $n b^2 t$.

→ The probable no. of α -particles coming within the distance of an impact parameter ' b ' of nucleus is given by $(n b^2 t n Q)$. $b \rightarrow$ impact parameter.

→ No. of α -particles ' N ' that are scattered thru an angle ' θ ' and strike unit area of screen ' S ' at a distance ' x ' is

$$N = t n Q \frac{(Z z e^2)^2}{4 (4 \pi \epsilon_0)^2 x^2 (m v_0^2)^2 \sin^4 \frac{\theta}{2}}$$

This is known as "Rutherford scattering formula".

No. of scattered particles per unit area is proportional to

- (i) Inverse of $\sin^4(\theta/2)$ (ii) Thickness ' t ' of scattering material
- (iii) Z^2 (square of atomic no. of scatterer) (iv) Inverse square of KE of α -particle.

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KE of electron: TE of electron = $1:1$

PE of electron: TE of electron = $2:1$

Con dn for elliptical orbit is $\frac{n_\phi}{n} = \frac{b}{a}$ $a, b \rightarrow$ semi major & minor axes
 $n_\phi \rightarrow$ azimuthal quantum number

According to selection rule only those transition are possible $\Delta n_\phi = \pm 1$

"Uhlenback" & "Goudsmit" put forward hypothesis of electron spin

Max no. of electrons allowed in a subshell are $2(2l+1)$ $l = 0, 1, 2, \dots$

Introduction of Relativity correction by Sommerfeld account for fine structure of spectral lines.

Sommerfeld's fine structure const $\alpha = \frac{1}{137}$

Sommerfeld also considered variation of mass with velocity.

The innermost electron has velocity $0.007c$.

Total KE of reduced mass system is $T_{KE} = \frac{1}{2} \mu \dot{r}^2 + \frac{1}{2} \mu r^2 \dot{\phi}^2$ $r = r_n + r_e$

Effect of finite mass on Rydberg const: $R_H = R \left(\frac{1}{1 + \frac{m}{M}} \right)$ $m \rightarrow$ mass of electron
 $M \rightarrow$ nucleus mass

Note- Rydberg const is slightly less than if nucleus at rest and wavelengths are slightly greater than those corresponding to an infinite heavy nucleus.

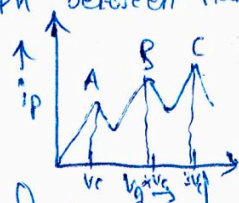
$R_H \rightarrow$ new value
 $R \rightarrow$ old value

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variation of Rydberg const with mass of nucleus led to discovery of deuterium. Ryd const for deuterium is slightly greater than that of hydrogen and hence spectral lines of deuterium are shifted to wave lengths slightly shorter than those of hydrogen.

Frank & Hertz exp reveals existence of discrete stationary states of electrons.

The "inelastic collisions" ^{between electrons & atoms of mercury} results in excitation of atoms to diff quantum states which are marked discontinuities on graph between plate current & grid voltage.



A sharp drop in current will be observed each time when grid potential ' V_g ' exceeds nV_c where $n=1, 2, \dots$, ' n ' corresponds to no. of inelastic collisions.

Separation in volts between successive peaks gives 'Critical Potential'. Atoms cannot be excited if accelerated electrons have energy less than eV_c .

Ionization Potential of hydrogen is 13.6V [Remember ' V ' denotes ' eV ' energy].

VECTOR ATOMIC MODEL

- Spatial quantization was proposed by "Sommerfeld".
- Two fundamental postulates of vector atom model was experimentally verified by "Stern & Gerlach" while studying behaviour of atoms in "Nonhomogeneous" magnetic field.
- $L = \sqrt{l(l+1)} \frac{h}{2\pi}$, $S = \sqrt{s(s+1)} \frac{h}{2\pi}$, Total orbital angular momentum $P_L = \sqrt{L(L+1)} \frac{h}{2\pi}$
 $(l = n - 1)$ the lowest possible value of n is zero. If l_1 & l_2 of two elec then $L = l_1 + l_2$ to $|l_1 - l_2|$
- For even no. of electrons 'S' must be integer but in case of odd 'S' is rational.

- Total angular momentum $P_j = j \frac{h}{2\pi}$, $j = l \pm s$, $+$ → For parallel spin
 $-$ → For anti " "

Magnetic moment $\mu_L = \frac{e}{2m} P_L = \left(\frac{eh}{4\pi m} \right) l$ For orbital electron
 $(\mu_L = i \times A)$

$$\mu_B = \frac{eh}{4\pi m} = 9.2 \times 10^{-24} \text{ Amp-m}^2$$

Gyromagnetic ratio $G = g \left(\frac{e}{2m} \right)$ orbital
 For elec $g = 1$
 $\Rightarrow G = 8 \times 10^{10} \text{ c/kg}$ ✓

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In some cases, the interaction between spin & orbital vectors of individual electrons is stronger than between either spin vectors or orbital vectors of diff electrons. In such cases J-S coupling is effective.

Electrons enter various subshells in the order of increasing energy.

Aufbau Principle:- subshell of lower energy is filled up first & subshell of higher energy is filled up later.

Fully filled & half filled orbitals have "extra stability".

SELECTION RULES:

- ① $\Delta J = 0, \pm 1$
- ② $\Delta L = \pm 1$
- ③ $\Delta S = 0$
- ④ $\Delta m_L = 0, \pm 1$
- ⑤ $\Delta m_S = 0, \pm 1$
- ⑥ $\Delta m_S = 0$

> oppositely directed transitions do not occur. $\Delta L = -1, \Delta J = +1$ \rightarrow no transition
 $\Delta L = +1, \Delta J = -1 \rightarrow$ no transition.

> The fine structure of H α line should have 5 components.

> Fine structure of sodium D line is Doublet.