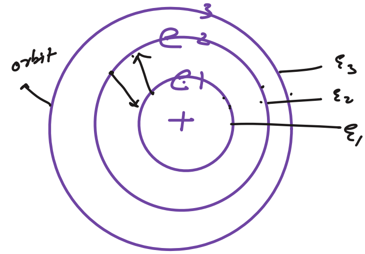
BOHR'S MODEL (1913)

Combined – Classical + Quantum

I Stationary orbits (Stability)

- e^-s move in specific "stable orbits" w/o radiating energy
→ Stationary orbits



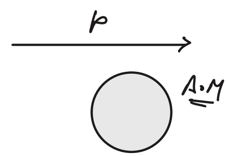
II Quantization Condition (select of orbits)

→ e^-s can revolve only in those orbitals whose angular momentum is int multiple of $\hbar = \frac{h}{2\pi}$

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

n → P.Q.no.

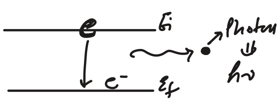
n → 1, 2, 3, 4, 5



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

III Frequency Condition

– Rad is emitted only when an e^- jumps from higher energy (E_i) to lower energy E_f



$E = \varepsilon_i - \varepsilon_f$

$$\boxed{h\nu = \varepsilon_i - \varepsilon_f}$$

Derivation for r, E, V

I> Radius

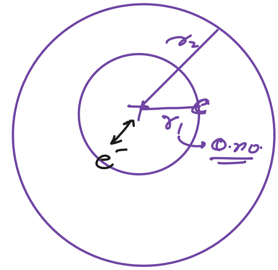
(1) $mvr = n\hbar$ → Q.M

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

(2) $F_e = F_c$ → C.M

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

$K\frac{q_1 q_2}{r^2}$, $e^- = e$, $q_2 \to Ze$



from -1 $\quad v = \frac{nh}{2\pi m r}$

put in (2)

$$\frac{1}{\cancel{4\pi}\varepsilon_0}\frac{KZe^2}{\cancel{r^2}} = \frac{\cancel{m}}{r}\left(\frac{n^2h^2}{\cancel{4}\pi^{\cancel{2}} m^{\cancel{2}} r^{\cancel{2}}}\right)$$

$$\boxed{r = \frac{\varepsilon_0 n^2 h^2}{\pi m Z e^2}} = \boxed{r = 0.53\,Å \times \frac{n^2}{Z}}$$

$r = 0.53\,Å \times \frac{1}{1} = a_0$ → Bohr radius

$$\boxed{r = \frac{a_0 n^3}{Z}}$$

II Velocity

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

→ $v = \frac{nh}{2\pi m}\cdot\frac{\pi m Z e^2}{\varepsilon_0 n^2 h^2}$

$$\boxed{v = \frac{Ze^2}{2\varepsilon_0 n h}}$$

$$\boxed{v \propto \frac{1}{n}}$$

$$\boxed{v = 2.18\times10^{6}\,\frac{Z}{n}}\ \text{m/sec}$$

III Total Energy of e^- in orbital

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

1 K.E

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{Ze^2}{2\epsilon_0 nh}\right)^2$$

$$\boxed{K.E = \frac{1}{2}\,\frac{mZ^2e^4}{4\,\epsilon_0^2 n^2 h^2}}$$

$$\boxed{r = \frac{\epsilon_0 n^2 h^2}{\pi m Z e^2}}$$

2) P.E $= \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$

$$= \frac{1}{4\pi\epsilon_0}\frac{(-e)(Ze)}{r^2}$$

$$P.E = -\frac{1}{4\pi\epsilon_0}\frac{Ze^2}{r^2}$$

$$= -\frac{1}{4\pi\epsilon_0}\,Ze^2\left(\frac{\pi m Z e^2}{\epsilon_0 n^2 h^2}\right)^2$$

$$\boxed{P.E = -\frac{mZ^2e^4}{4\,\epsilon_0^2 n^2 h^2}}$$

$$K.E = -\frac{1}{2}\,P.E$$

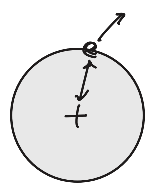
$$\boxed{P.E = -2\,K.E}$$

III T.E

$$E = K.E + P.E$$
$$= K.E - 2K.E$$

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

-ve ?



Made with Goodnotes

$$K.E = \frac{m z^2 e^4}{8 h^2 \varepsilon_0^2 n^2} = -E$$

$$E = -K.E$$

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

$$E_1 = -13.6\,eV$$

E_1

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

$$\boxed{P.E = 2\,T.E}$$

Ques Calculate radius of 2nd Excited state of Li^{++}

3

1e

3 p

3 e

Sol

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

$$= \frac{a_0 (3)^2}{3} = \frac{\cancel{9}^{\,3}}{\cancel{3}} \times 0.53\,Å$$

$$\boxed{r = 1.06\,Å}$$

4

3 = 2nd E

2 = n

1

g.s

For H-atom

$$E = \frac{-13.6\,\boxed{Z^2 = 1}}{n^2} \quad \rightarrow \text{H-atom}$$

$$E_1 = \frac{-13.6}{1^2} = -13.6$$

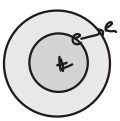
$$E_2 = \frac{-13.6}{2^2} = -3.4\,eV$$

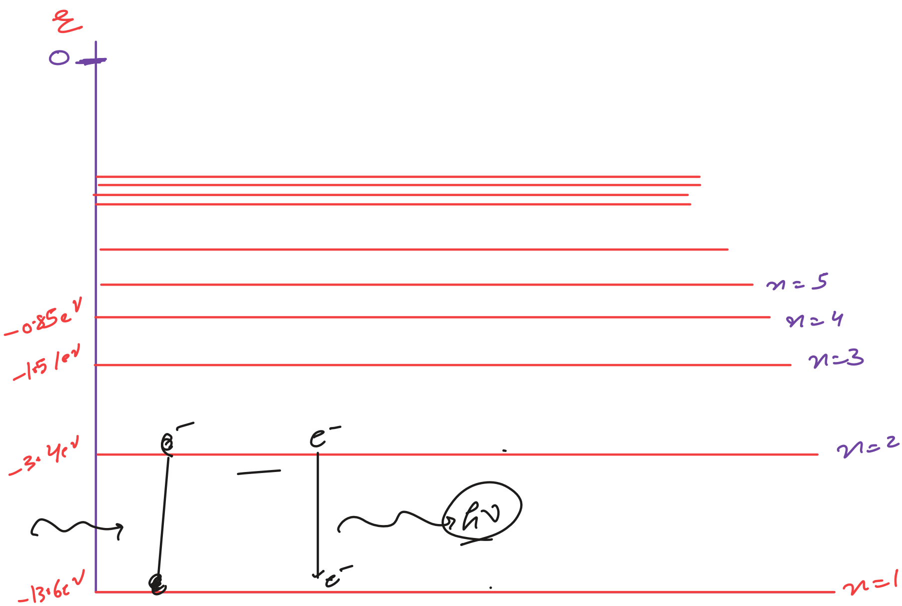
$$E_3 = \frac{-13.6}{3^2} = -1.51\,eV$$

$$E_4 = 0.85\,eV$$

$$E_5 = 0.54\,eV$$

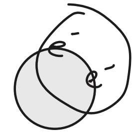
$$E_6 = -0.37$$





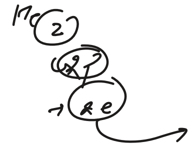
$$h\nu = \frac{hc}{\lambda} = E_2 - E_1$$

Drawbacks



1) Only true for H-atom, H-like atom

He^+, Li^{++}, Be^{+++}



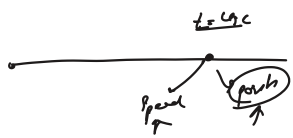
2) Cannot explain spectra of multi-e^-

3) Violates Heisenberg uncertainity principle

um ← $\boxed{\Delta x \Delta p = \frac{\hbar}{2}}$

↳ we can't measure position and momentum simultaneously

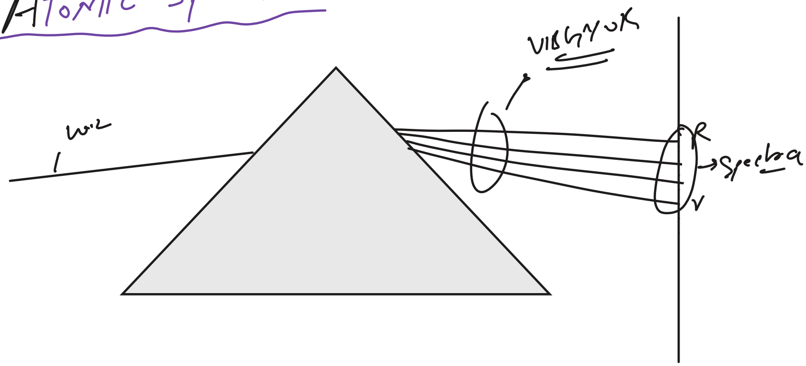
$\Delta x \propto \frac{1}{\Delta p}$ → speed



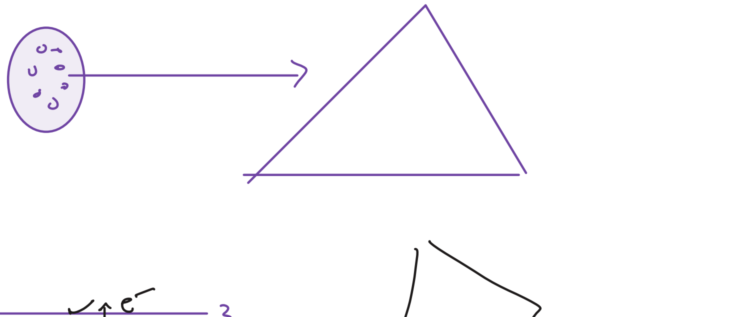
→ $r = \frac{n^2 h^2 \epsilon_0}{\pi m Z e^2} = \frac{a_0 n^2}{Z}$

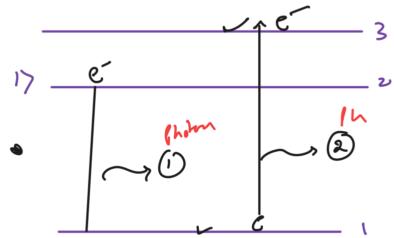
→ $p = mv = m \frac{Ze^2}{2nh\epsilon_0}$

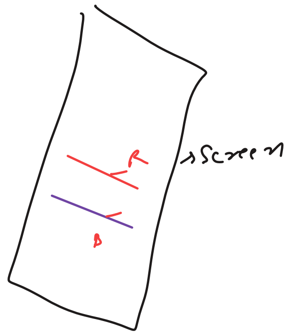
ATOMIC SPECTRA



1) Emission Spectra







$E = \frac{hc}{\lambda_2}$ → B

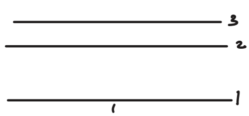
$E_1 = \frac{hc}{\lambda_1}$ → R

E_n

- why e^- comes back to g.s

→ To stable state

Qu find E, λ of photon emitted when e^- in H-atom makes transit from $n = 3$ to $n = 1$



Sol $E = ?$ $\lambda = ?$

$E = E_3 - E_1$

$E = \frac{-13.6}{n_1^2} - \frac{-13.6}{n_2^2}$

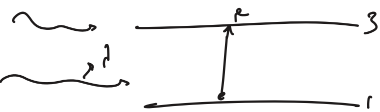
$E = E_3 - E_1$

$= \frac{-13.6}{3^2} - \left(\frac{-13.6}{1^2}\right)$

$= -1.51\,eV + 13.6\,eV$

$\boxed{E = 12.09\,eV}$

→ Energy of ph



$E = \frac{hc}{\lambda} = 12.09\,eV$

$\frac{hc}{12.09\,eV} = \lambda$

$\frac{1240\,\cancel{eV}\,nm}{12.09\,\cancel{eV}}$

$\boxed{\lambda = 1024\,Å}$

Shortcut

$E = E_{n_2} - E_1$

E of ph $\qquad n_2 \longrightarrow n_1$

$E = \frac{-13.6\,eV\,z^2}{n_2^2} - \frac{(-13.6)\,z^2}{n_1^2}$

$E = z^2 \times 13.6\,eV \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\frac{hc}{\lambda} = z^2 \times 13.6 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

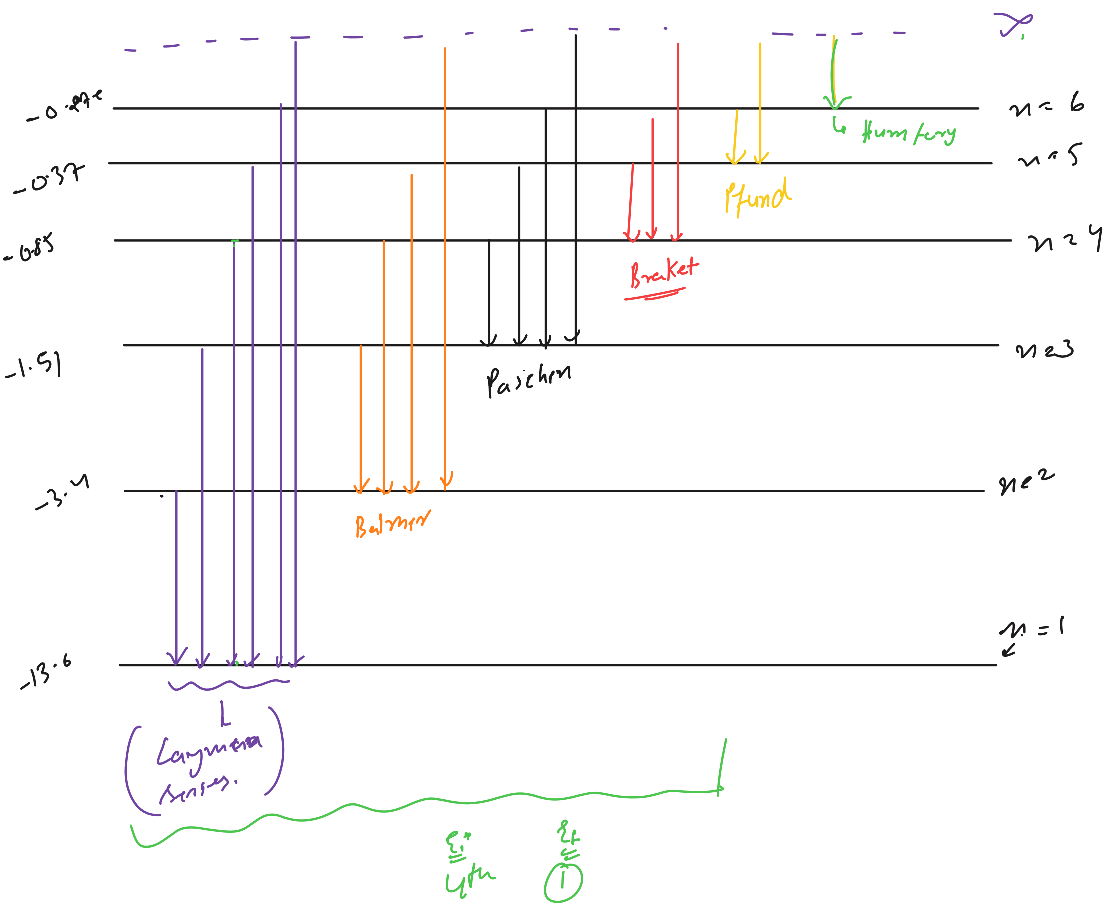
$\frac{1}{\lambda} = \frac{13.6}{hc}\, z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

↓ Rydberg Cnst → $1.09 \times 10^7\, m^{-1}$

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

$$\frac{1}{R} = 910\,Å,\ 911\,Å,\ 912\,Å$$

$$R^{-1} = \frac{1}{R}$$



Q) Find λ of photon emitted when e^- falls from $n=2$ to $n=1$

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

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

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

$$\lambda = \frac{4}{3}\frac{1}{R} \rightarrow 912$$

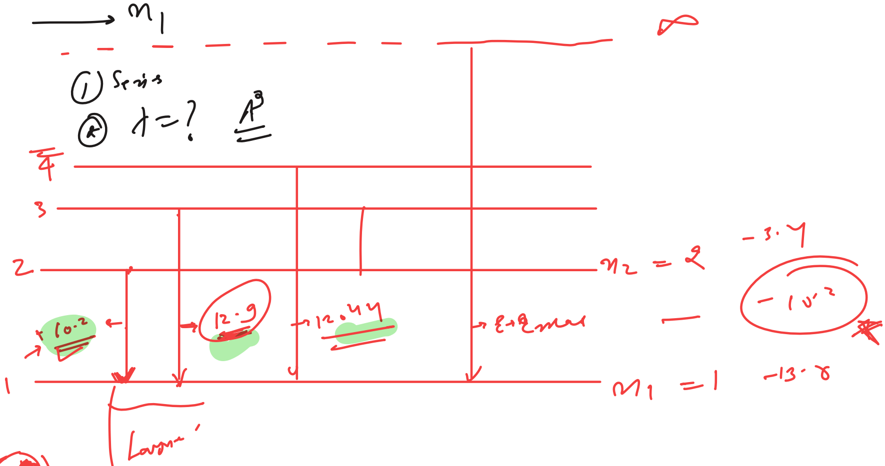
$$\lambda = \cancel{912}^{304}\,Å \times \frac{4}{\cancel{3}}$$

$$\boxed{\lambda = 1216\,Å}$$

Qu $n_3 \longrightarrow n_1$

① Series

② $\lambda = ?$ Å



#

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

$\uparrow\downarrow E \propto \frac{1}{\lambda\uparrow}\downarrow$

② $\infty \longrightarrow 1$

$\Rightarrow E_{max}$

$\Rightarrow \lambda \rightarrow$ smallest

→ Longest wavelength

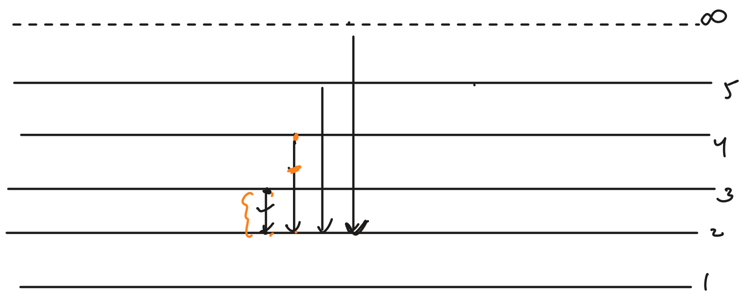
Qu 1) Longest wavelength of Layman Series

$n_2 \longrightarrow n_1$

$E_2 - E_1 = \frac{hc}{\lambda}$

- Smallest Transition → Longest wavelength
- Largest transition → Smallest wavelength.

Qu Find Smallest and Largest wave of Balmer Series



(1) Longest wave $\downarrow E \propto \frac{1}{\lambda \uparrow}$ Sm Tr $\lambda \uparrow$

$n=3 \rightarrow n=2$

$(3)^2$

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

$$= R\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$\frac{1}{\lambda} = R\left[\frac{5}{36}\right]$$

$\frac{1}{R} = 910, 911, 912$

18.2

$$\lambda = \frac{36}{5} \times \cancel{910}$$

$$\boxed{\lambda = 3648\,\mathring{A}}$$

(2) Smallest λ

$n_i = \infty$ $n_f = 2$

$E\uparrow$

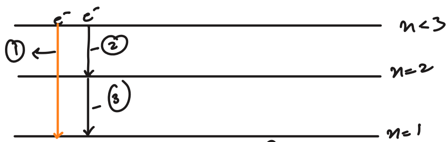
$$\frac{1}{\lambda} = R\left\{\frac{1}{4} - \frac{1}{\infty^2}\right)$$

$\Rightarrow \lambda = \frac{4}{R}$

$$\boxed{\lambda = 4 \times 912\,\mathring{A}}$$

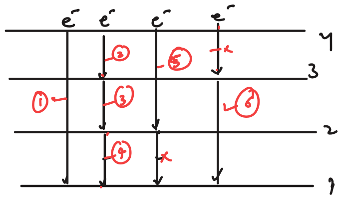
No. of Spectral lines

i) $n_3 \longrightarrow n_1$



Total Tran = 3

Q $n=4$ to $n=1$



λ

R

Total lines → 6

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

$n_2 = 4$, $n_1 = 1$

$$\frac{(3)(4)}{2} = 6 \text{ lines}$$