Quantization of Energy.

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Syllabus

- Postulates of Bohr's Atomic Model
- Derive expression of radius of n^{th} orbit, velocity of electron in n^{th} orbit and total energy of electron in n^{th} orbit of H-atom.
- Obtain the expression for wavelength of spectral lines.
- obtain the mathematical expression of different spectral line series of H-atom
- Differentiate ionization and excitation potential.
- Explain emmision and absorption spectra.
- De-Broglie hypothesis
- X-Rays define,
- Describe modern coolidge tube method for the production of x-rays with quality & quantity
- Illustrate different properties of x-rays.
- Solve numeric related to quantization of Energy.

Atomic Models

- Thompson's Atomic Model
- Rutherford's Atomic Model
- Bohr's Atomic Model ✓
- Sommerfelt Relattivistic Atomic model
- Vector Atomic Model

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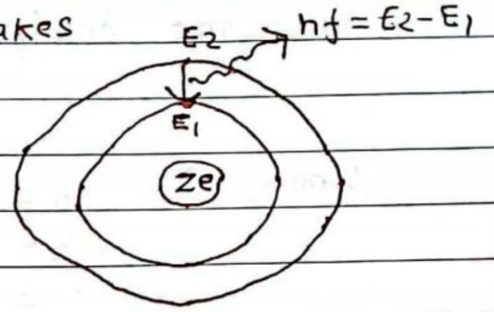
- **Bohr's Frequency condition** :- Electron makes transition from one energy state to another energy state by absorbing or radiating energy. Then it emitts or absorbs photons which has energy equal to the energy difference b/n. initial and final energy state.



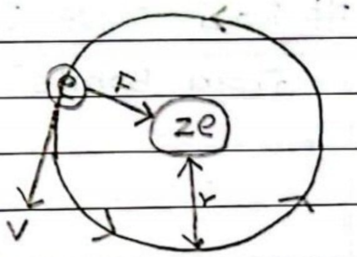
Let E_i and E_f be the energy of initial and final state of energy. Then the energy of emitted or absorbed photons is given by

$$\boxed{hf = E_i - E_f}$$

Bohr's Imp postulates

Bohr's Theory of H-atom

- Bohr's theory was able to explain the model of hydrogen and hydrogen like atoms.
- Bohr's postulated that an electron revolves around nucleus in fixed orbit. In this condition, electrostatic force b/n electron and neclues ~~is~~ in the orbit, provides the centripetal force required to revolve around nucleus. as shown in fig.



Let ze be the charge of nucleus, e be the charge of electron and r be the radius of atom. Then the electrostatic force is given by:

$$\boxed{F_e = \frac{1}{4\pi\varepsilon_0}\frac{ze.e}{r^2}} \quad \text{------------} (1)$$

where $z =$ Atomic number.
$\varepsilon_0 =$ permitivity of free space.

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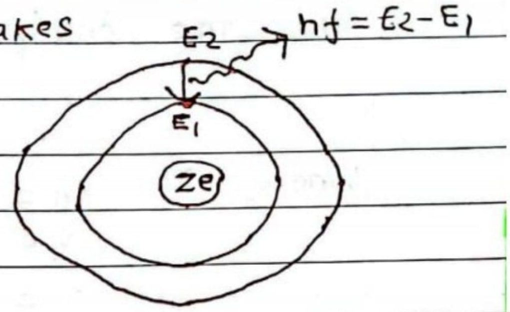

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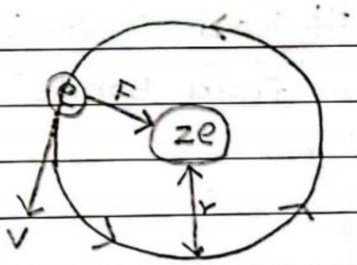

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And, the centripetal force for electron is given by ---------- (II)

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

Where, m = mass of e^-.
v = velocity of e^-
r = radius of atom.

According to Bohr's theory

$$F_e = F_c$$

$$\frac{1}{4\pi\varepsilon_0} \cdot \frac{ze^2}{r^2} = \frac{mv^2}{r}$$

$$\text{or, } \frac{1}{4\pi\varepsilon_0} \frac{ze^2}{r} = mv^2 \text{ ------ (III)}$$

Radius of Bohr's stationary orbit.

From Bohr's 2nd postulate;

$$mvr = n \times \frac{h}{2\pi}$$

$$\text{or, } v = \frac{n \times h}{2\pi mr} \text{ -------- (IV)}$$

Substituating (IV) in (III) we get,

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

$$\text{or, } \frac{1}{\varepsilon_0} ze^2 = \frac{\cancel{m} \times n^2 \times h^2}{\pi m^2 r}.$$

$$\text{or, } r = \frac{\varepsilon_0 n^2 h^2}{\pi z e^2 m}$$

$$\therefore \boxed{r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m z e^2}.}$$

Bohr's radius is the radius of lowest orbit of H-atom

a_0

By putting all standard values we get,

$r_1 = 0.53 A^o$ #

$$\boxed{\therefore r_n = 0.53 \times n^2 A^o}$$

ASSIGNMENT

Q) Why is electron revolving around nucleus of an atom.

→ It is because the electrostatic force between electrons and nucleus provides the centripetal force to the electron to make it move around the nucleus.

Q) Why thin gold foil was used in α-particle scattering experiment?

→ In thick foil, the entire KE of the α-particles will be absorbed and so α-particles will not be able to penetrate through the foil that's why thin gold foil is used to avoid multiple scattering and it was easy to peneterate also.

Velocity of electron

we have,

From Bohrs Quantization condition,

$m v_n r_n = n \times \frac{h}{2\pi}$ where $n = 1, 2, 3 ----$.

or, $V_n = \frac{n \times h}{2\pi m \cdot r_n}$ ———— (I)

We have, $r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2}$ ———— (II)

Putting the value of (II) in (I) we get

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$$V_n = \frac{n \times h}{2\pi m \left(\frac{\varepsilon_0 n^2 h^2}{\pi m e^2}\right)}$$

$$\boxed{\therefore V_n = \frac{e^2}{2\varepsilon_0 n h}} \quad \text{------} \quad (III)$$

Which is the required expression of velocity of electron in n^{th} stationary circular orbit.

Eqn (III) shows that $\boxed{V_n \propto \frac{1}{n}}$ i.e. speed of e^- in n^{th} orbit is indirectly porpotional to principal quantum no.

more no. of shell, less velocity / speed.

Total Energy of the electron in n^{th} orbit

An electron is revolving around a necleus, it has Kinetic Energy. Similarly it is attracted towards the necleus by electrostatic force of attraction, it has Potential Energy.

$\therefore$ Total Energy of electron in n^{th} orbit,

$$E_n = KE + PE \quad \text{——} \quad (I)$$

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

$$= \frac{1}{2} m \times \left(\frac{e^2}{2\varepsilon_0 n h}\right)^2$$

$$= \frac{1}{2} m \frac{e^4}{4 \varepsilon_0^2 n^2 h^2}$$

$$= \frac{m e^4}{8 \varepsilon_0^2 n^2 h^2} \quad \text{——} \quad (II)$$

Now, P.E is given by,

$$P.E = \frac{1}{4\pi\varepsilon_0} \frac{e\cdot(-e)}{r_n}$$

$$= -\frac{1}{4\pi\varepsilon_0} \frac{e^2}{r_n}.$$

$$= -\frac{1}{4\pi\varepsilon_0} e^2 \times \frac{\pi m e^2}{\varepsilon_0 n^2 h^2} \quad \left[\because r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2}\right]$$

$$\therefore PE = -\frac{me^4}{4\varepsilon_0^2 n^2 h^2} \text{ ——— (III)}$$

putting (II) and (III) in (I) we get.

$$E_n = \frac{me^4}{8\varepsilon_0^2 \cdot n^2 h^2} - \frac{me^4}{4\varepsilon_0^2 n^2 h^2}$$

$$= \frac{me^4 - 2me^4}{8\varepsilon_0^2 n^2 h^2}$$

$$\therefore \boxed{E_n = -\frac{me^4}{8\varepsilon_0^2 n^2 h^2}} \text{ ——— (IV)}$$

putting the values of constants in (IV) we get

$$\boxed{E_n = -\frac{13.6 Z^2}{n^2} eV} \text{ ——— (V)}$$

NOTE:

1) The (-ve) sign in the eqn (IV) indicates that upper orbits have more energy than lower orbits.

i.e when $n = \infty$ $E_n = 0$ $\left(\frac{\text{something}}{\infty} = 0\right)$

Gap Decreases & energy increases as going to upper orbits.

* (-ve) signs also indicates the attraction on electron by proton.

{ $E \propto -1/n^2$
As N increases, negative energy decreases }

1st Excitation state = 2nd shell (n = 2)

$E_1 = -13.6$

$E_2 = -3.4$

$E_3 = -1.511$

$\vdots$

$E_\infty = 0$

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

Energy Emitted during transition of an atom.

→ Let E_1 and E_2 be the energy of an electron in the lower and higher stationary orbits respectively

Then, $\Delta E = E_2 - E_1$

$$\text{or, } \Delta E = -\frac{me^4}{8\varepsilon_0^2 (n_1)^2 \cdot h^2} - \left(-\frac{me^4}{8\varepsilon_0^2 (n_2)^2 h^2}\right)$$

$$\text{or, } \Delta E = \frac{me^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{(n_2)^2} - \frac{1}{(n_1)^2}\right] \quad \text{—— (1)}$$

$$\text{or, } \boxed{\Delta E = -13.6\left[\frac{1}{(n_2)^2} - \frac{1}{(n_1)^2}\right]} \text{ eV}$$

For Frequency,

From (1) we have, $\Delta E = \frac{me^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$

Or, $hf = \frac{me^4}{8\varepsilon_0^2 h^2}\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$

$\therefore f = \frac{me^4}{8\varepsilon_0^2 h^3}\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$ ——— (11)

$= C \cdot R \left[\frac{1}{(n_2)^2} - \frac{1}{(n_1)^2}\right]$

For wavelength,

$F = \frac{C}{\lambda} = \frac{me^4}{8\varepsilon_0^2 h^3}\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$

$\therefore \frac{1}{\lambda} = \frac{me^4}{8\varepsilon_0^2 ch^3}\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right]$

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

where, $\bar{\lambda} = \frac{1}{\lambda}$ = wave number

no. of waves contained per unit length in vacuum

And R is Rydberg's constant,

$R = \frac{me^4}{8\varepsilon_0^2 ch^3} = 1.097 \times 10^7$ per m.

Q) Hydrogen atom is stable in ground state. Why?

→ In H-atom, ground state electron is the electron in lowest possible state (i.e 1st orbit). So there is no possiblity of downward transition of electron below that state. So, it is stable in ground state.

Q1) A hydrogen atom is in ground state. what is the quantum no. to which it will be excited absorbing of photon of Energy 12.75 ev?

→ Given, $\Delta E = 12.75\,ev$

we have $\Delta \mathcal{E} = 13.6 \left(\frac{1}{(n_1)^2} - \frac{1}{(n_2)^2} \right) ev$

$$\frac{12.75}{13.6} = \frac{1}{(1)^2} - \frac{1}{(n_2)^2}$$

or, $$\frac{15}{16} = 1 - \frac{1}{(n_2)^2}$$

or, $$\frac{1}{(n_2)^2} = 1 - \frac{15}{16} = \frac{1}{16}$$

$\therefore n_2^2 = 16 \Rightarrow n_2 = 4$

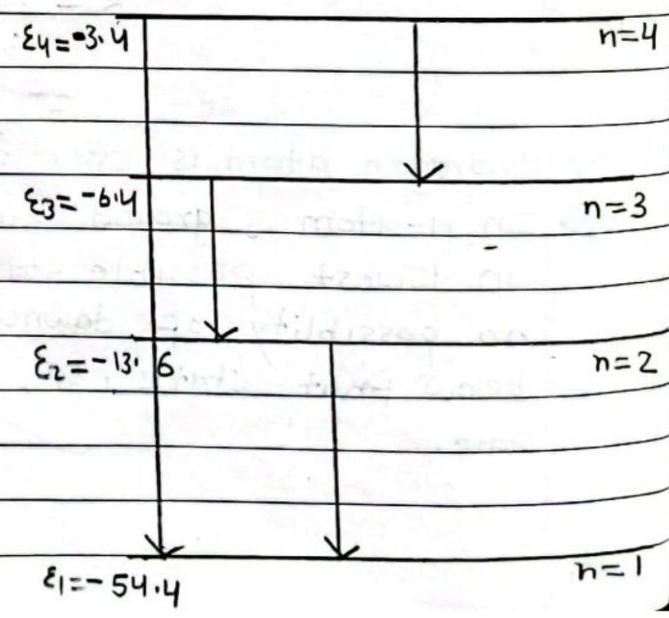
$\therefore$ Required quantum no. is 4

Q2) The energy level of an atom are shown in Figure.

a) Find the shortest wavelength in the given transition.

b) The longest wavelength in the given transition

c) Energy of photon emitted in transition of first excited state to ground state.



→ Hints:

shortest wavelength.

$\Delta \mathcal{E} = \mathcal{E}_4 - \mathcal{E}_1$

Longest wavelength

$\Delta \mathcal{E} = \mathcal{E}_4 - \mathcal{E}_3$

c) $\Delta \mathcal{E} = \mathcal{E}_1 - \mathcal{E}_2$

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→ Solution :- Here.

a) For shortest wavelength, [choose longestd]

$$\Delta E = E_4 - E_1$$

$$h \times F = 3.4 - (-54.4) \text{ ev}$$

$$h \times \frac{c}{\lambda} = 57.8 \times 1.6 \times 10^{-19}$$

$$\text{or, } \lambda = \frac{h \times c}{9.248 \times 10^{-18}} = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{9.248 \times 10^{-18}}$$

$$\text{or, } \lambda = 2.147 \times 10^{-9} \text{ m}$$

b) For longest wavelength [choose shortest d]

$$\Delta E = E_4 - E_3$$

$$h \times \frac{c}{\lambda} = 3.4 - (-6.4) = 9.8 \text{ ev} = 9.8 \times 1.6 \times 10^{-19}$$

$$\therefore \lambda = \frac{h \times c}{9.8 \times 1.6 \times 10^{-19}} = \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{9.8 \times 1.6 \times 10^{-19}}$$

$$\therefore \lambda = 4.7 \times 10^{-7} \text{ m}$$

c) Energy of photon emitted in transition of First exicted state to ground state. is given by

$$\Delta E = E_2 - E_1$$

4 $$= -13.6 - (-54.4)$$

$$= 40.8 \text{ ev}$$

$$= 40.8 \times 1.6 \times 10^{-19} \text{ joule}$$

3 $$= 6.528 \times 10^{-18} \text{ joule}$$

2

1

SPECTRAL SERIES OF HYDROGEN

$$\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$ This is the general equation.

a) Lyman Series :- When electron jumps from higher Energy level to ground state i.e $n_1 = 1$ and $n_2 = 2, 3, 4$ ------ is called lyman series.

Here, $n_1 = 1$

$n_2 = 2, 3, 4$ ------ ∞

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

For longest wavelength of lymen series.

$n_2 = 2$.

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

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

or, $$\boxed{\lambda_l = \frac{4}{3R}}$$ ← longest wavelength

For shortest wavelength,

$n_2 = \infty$

Then $$\frac{1}{\lambda_S} = R\left(1 - \frac{1}{(\infty)^2}\right) = R$$

$\therefore$ $$\boxed{\lambda_S = \frac{1}{R}}$$ which is shortest wavelength for lyman series.

Q) Find the ratio of shortest to longest wavelength for lyman series?

a) we know that, For lyman series.

longest wavelength (λ_L) = $4/3R$

Shortest wavelength (λ_s) = $1/R$

AT ①, $\frac{\lambda_s}{\lambda_L} = \frac{1}{R} \times \frac{3R}{4} = \frac{3}{4}$

			lies.
L	Lyman series	→	UV
B	Balmer series	→	V (visiable)
P	Paschen "	→	I
B	Brackett "	→	I
P	PFund "	→	FI (far Infrared)

b) Balmer series :- when electron jumps from higher energy level to 1st Exicted state. i.e. $n_1 = 2$ and $n_2 = 3, 4$ ------ called Balmer series.

Longest wavelength (λ_L) = $\frac{36}{5R}$ is the longest wavelength called H_α - line

$n_2 = 3$, $n = 2$, α, β, γ

$$\begin{cases} H_\beta = n_1 = 2 & n_2 = 4 \\ H_\gamma = n_1 = 2 & n_2 = 5 \\ H_\delta = n_1 = 2 & n_2 = 6 \end{cases}$$

Shortest wavelength (λ_s) = $n_1 = 2$ $n_2 = \infty$

Then, $\frac{1}{\lambda_s} = R\left(\frac{1}{4} - \frac{1}{\infty}\right)$

$\therefore$ $\boxed{\lambda_s = 4/R}$

Ratio of λ_s to λ_L

$$\frac{\lambda_s}{\lambda_L} = \frac{5}{9}$$

c) **Paschen Series** :- It is the spectral series when electron jumps from higher energy level to second exitation state.

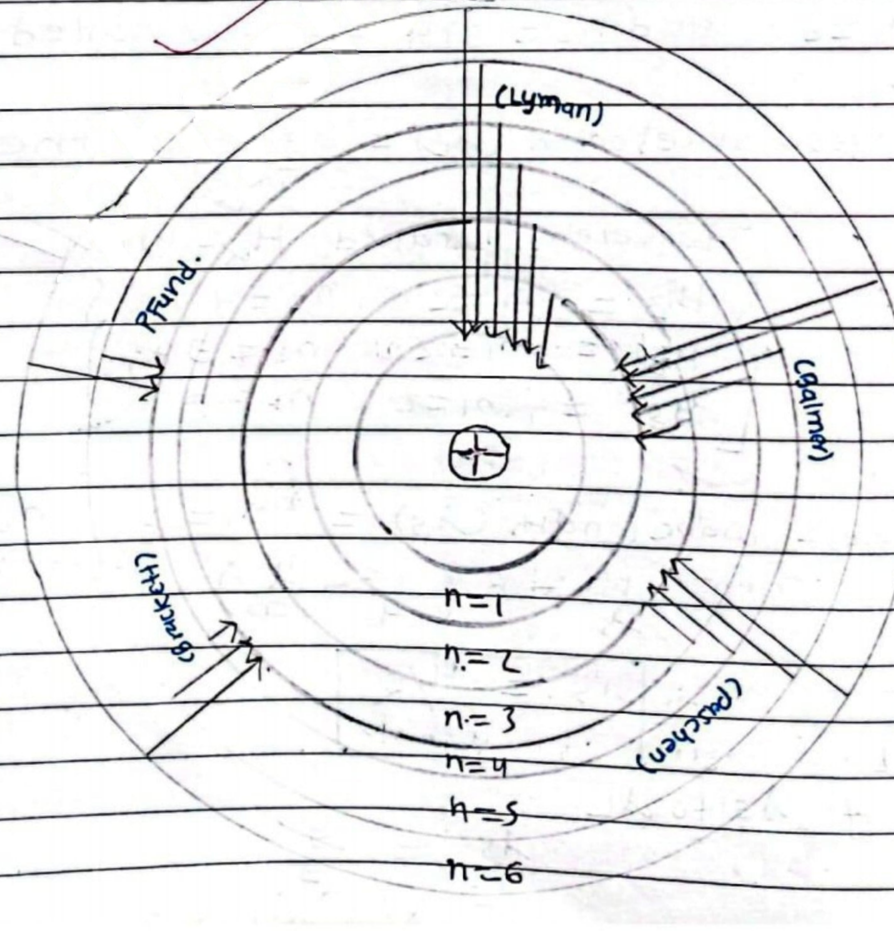
$$n_1 = 3 \quad \text{and} \quad n_2 = 4, 5 \ldots \infty$$

d) **Brackett series** :- It is the spectral series obtained when an electron jumps from higher energy level to 3rd excitation state.

$$n_1 = 4 \quad n_2 = 5, 6 \ldots \infty$$

e) **Pfund Series** :- It is the spectral series obtained when an electron jumps from higher energy level to 4th exicited state.

$$n_1 = 5 \quad n_2 = 6, 7 \ldots \infty$$



Some Important Conclusions :-

(Imp for MCQs)

- Shortest Wavelength (λ_s) $= \frac{n^2}{R}$ (n = 1, 2, 3, 4)
- No. of emission lines $= \frac{n(n-1)}{2}$
- $\lambda_{Pfund} > \lambda_{brackett} > \lambda_{paschen} > \lambda_{balmer} > \lambda_{lyman}$

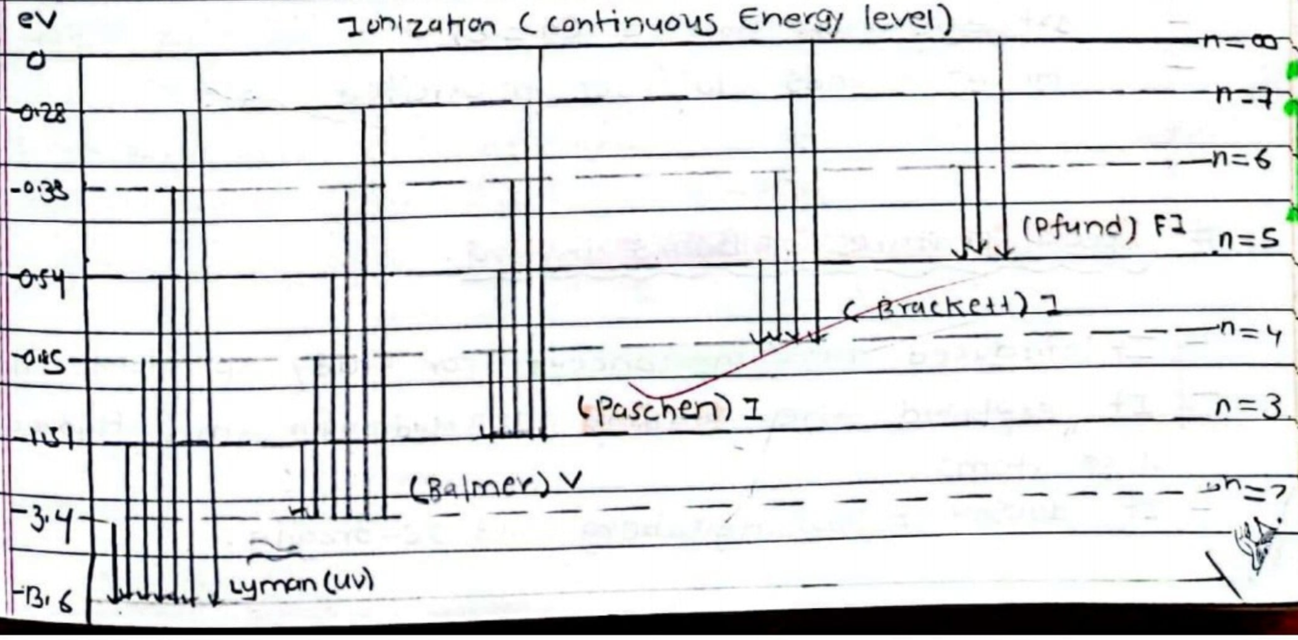
Series	Shortest λ	Longest λ	Ratio
Lyman	$1/R$	$4/3R$	3 : 4
Balmer	$4/R$	$36/5R$	5 : 9
Paschen	$9/R$	$144/7R$	7 : 16
Brackett	$16/R$	$400/9R$	9 : 25
Pfund	$25/R$	$900/11R$.	11 : 36

n^2/R

It is in a sequence.

Energy Level diagram :

It is the diagrammatic representation of electron's energy in n^{th} orbit of H-atom.



We have $E_n = \frac{-me^4}{8\varepsilon_0^2 n^2 h^2}$.

on putting the value of constants.

$$E_n = -\frac{9.1\times10^{-31}\times(1.6\times10^{-19})^4}{8\times(8.85\times10^{-12})^2\times(n)^2\times(6.62\times10^{-34})^2}$$

or $E_n = -\frac{21.76\times10^{-19}}{n^2}$ Joule

$$\therefore \boxed{E_n = -\frac{13.6}{n^2}\ eV}$$

Now,

$$\left\{\begin{array}{lll} E_1 = -13.6/1\ eV & = -13.6\ eV \\ E_2 = -13.6/4\ eV & = -3.4\ eV \\ E_3 = -13.6/9\ eV & = -1.51\ eV \\ \vdots & \vdots \\ E_\infty = \frac{-13.6}{(\infty)^2} & = 0 \end{array}\right\}$$

Some Tips for MCQs

- Space diffrence btn. two EL decrease on increasing n.
- Lowest energy level = ground state (n=1)
- 1st exicitation state = (n=2)
- An e^- spends 10^{-8} sec in exicited state

Special Features of Bohr's Theory.

- It introduced quantum concept for study of atomic model
- It explained the stablity of Hydrogen and Hydrogen like atoms.
- It doesn't follow Heisnberg and De-Broglie.

- It explains about spectral series of hydrogen atom.
- It gives the concept of electronic orbits in an atom.
- It gives quantization condition.

Limitations of BAM.

- It was able to explain spectra of hydrogen and hydrogen like atoms only.
- It was not able to explain elliptical orbits.
- It fails to explain the wave nature of electron.
- It fails to explain the intensities of spectral lines
- It couldn't explain splitting of spectra under magnetic and electric field.

#	Excitation Energy	Excitation potential.
1)	It is the minimum energy required to raise electron from its ground state to excited state. (except $n=\infty$)	1) It is the minimum potential required to excite an electron from ground state to given excited state.
2)	$\Delta E = E_e - E_g$	2) $V_e = \frac{E_e - E_g}{e}$
3)	First exication Energy for H-atom is 10.2 eV	3) First excitation potential for H-atom is 10.2 V

Ionization Energy

It is the minimum energy required to eject an electron completely out of the atom.

$$\boxed{\begin{aligned} \Delta E_i &= E_{ionized} - E_{ground} \\ \Delta E_i &= \mathcal{E}_{\infty} - E_1 \end{aligned}}$$

Ionization Potential

It is the minimum potential required to eject knock out the electron completly out from the atom.

$$\boxed{V_i = \frac{\mathcal{E}_{\infty} - \mathcal{E}_1}{e}}$$

Emission Spectra.

It is the spectra of different wavelengths obtained when electrons in excited state jumps to lower energy state.

Spectrum is the arrangement of wavelengths of frequencies of radiation either in increasing or decreasing order.

Types of Emission Spectra.

1) Continous spectra → unbroken / continuous wavelength
→ produced by sun. bulb etc.

2) Line spectra → Discrete spectral lines having
→ particular wavelength
→ Produced by hydrogen

3) Band spectra → sperate / distinct group of spectral lines
→ spectra produced by CO_2.

Absorption spectra.

It is the spectra obtained when electron in lower energy is taken to higher energy state. It is particularly produced by cold and dilute gas.

For eg:- When white light is passed through red glass, it absorbs all the colours except red and gives absorption spectra.

DE-Broglie's Theory : Duality

"Nature loves symmetry"

De-Broglie (in 1924) suggested that matter like e^- & p^+ should also posses dual character (wave & particle) like light.

According to him, the moving particle sometimes behaves as a particle and sometime as a wave associated with moving particles. These waves are called the De-Broglie waves and corresponding wavelength is called De-Broglie wavelength. Given by.

$$\boxed{\lambda = \frac{h}{p}} \quad (p = \text{linear momentum} = mv)$$

Proof:

From planks theory of radiation, energy of photon is given by.

$$E = hf = \frac{hc}{\lambda} \text{ ——— (I)}$$

And from Einsteins mass energy relation.

$$E = mc^2 = m \times c \times c = p \times v \text{ ——— (II)}$$

$(v = c \text{ for photon})$

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From ① and ⑪

$$\frac{hc}{\lambda} = p \times c$$

$$\therefore \boxed{\lambda = \frac{h}{p}} \qquad \lambda \propto \frac{1}{p}$$ [greater momentum shorter wavelength and vice verse]

In terms of K.E

{ If $v = 0$, $\lambda = \infty$
$\lambda = 0$, $v = \infty$ }

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

$$\text{or, } E_K = \frac{1}{2m}(mv)^2$$

$$\text{or, } E_K = \frac{p^2}{2m}$$

$$\text{or, } p = \sqrt{2mE_K} = \frac{h}{\lambda} \qquad \left[\because \lambda = h/p\right]$$

$$\therefore \lambda = \frac{h}{\sqrt{2mE_K}}$$

Conclusions:

(1) $\lambda \propto 1/p$ [p = momentum = mv]

(2) $\lambda \propto n$ [n = principal quantum number] shell no.

(3) $\lambda \propto 1/v$ [v = velocity]

Uncertainity principle [Heisenberg's]

Werner Heisenberg (in 1927)

This principal states that, "it is impossible to determine precisely & simultaneously the values of both the members of pair of conjugate variables.".

- It applies only on microscopic bodies.
- It is used to calculate the probabilities for where things are and how will they behave.
- It says that, "we cannot measure the position (x) and the momentum (p) of the particle simultaneously."

"The more accurately we know one value less accurately we know the other."

Multplying togethers the error in measurement of position and momentum has to give a number greter than or equal to half of a constant called ($\hbar$)

$$\therefore \Delta x \cdot \Delta p \geq \hbar/2$$

$$\text{or, } \Delta x \cdot \Delta p \geq \frac{h}{4\pi} \quad (\hbar = h/2\pi)$$

$$\text{or, } \Delta x \cdot m \times \Delta v \geq h/4\pi$$

$$\text{or, } \Delta x \cdot m \geq h/4\pi \cdot \Delta v$$

where,

Δx = Error in position
Δv = " " velocity
Δp = " " Momentum

Uncertainity principle appears similar "to laugh & to contract mouth, which are not possible at same time".

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Q) Use heisenberg uncertainity principle to show that no electron exist inside nucleus.

→ According to Heisenberg uncertainity principle

$$\Delta x \cdot \Delta p = 1.054 \times 10^{-34}$$

If we assume e^- lies inside nucleus can be 10^{-14} m which is max size of nucleus.

Then,

$$\Delta x \cdot m \times \Delta v = 1.054 \times 10^{-34}$$

$$10^{-14} \cdot m \times \Delta v = 1.054 \times 10^{-34}$$

$$\Delta v = \frac{1.054 \times 10^{-34}}{10^{-14} \times (9.1 \times 10^{-31})}$$

$$\Delta v = 1.15 \times 10^{10} \text{ m/s}$$

Here, According to our assumption Δv inside nucleus is more than the velocity of light (i.e. 3×10^8 m/s) so our assumption is wrong.

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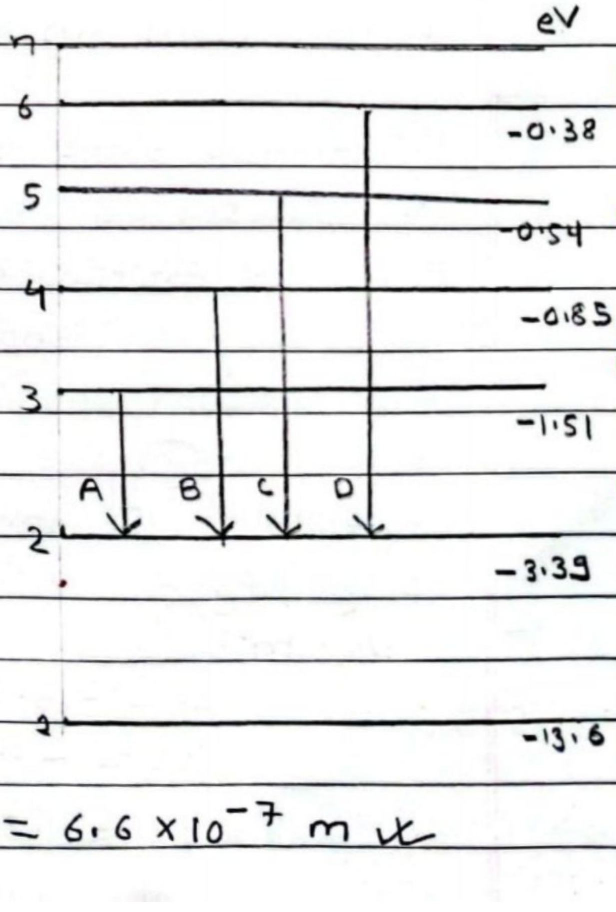
Short Questions.

1a) Which spectral series of H-atom observed at First? What region of e.m. spectrum this spectral series belongs?

→ Balmer series of H-atom ~~at~~ is observed at First

b) State Bohr's postulate of quantization of energy. Find out the wavelength of the lines associated with the transitions A, B, C, D marked in the Figure. show that the transitions that can occur give rise it lines that either in the ultra-violet or infra-red regions of spectrum. compare the result.

→ Bohr's postulate of quantization of energy states that, electron revolves only on those orbits For which the angular momentum is the integral multiple of $h/2\pi$.



Wavelength associated with A is given by:

$$\Delta E = E_3 - E_2$$

$$h \times \frac{c}{\lambda_A} = -1.51 - (-3.39) = 1.88 eV$$

$$\therefore \lambda_A = \frac{h \times c}{1.88 \times 1.6 \times 10^{-19}}$$

or, $\lambda_A = \dfrac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{1.88 \times 1.6 \times 10^{-19}} = 6.6 \times 10^{-7}$ m

$$\lambda_B = \frac{h \times c}{E_4 - E_2} = \frac{6.26 \times 10^{-34} \times 3 \times 10^{8}}{-0.85-(-3.39)\,eV} = \frac{1.9878 \times 10^{-25}}{2.54 \times 1.6 \times 10^{-19}}$$

or, $\lambda_B = 4.89 \times 10^{-7}$ m

$$\lambda_c = \frac{h \times c}{(E_5 - E_2) \times 1.6 \times 10^{-19} J} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{(-0.54-(-3.38)) \times 1.6 \times 10^{-19}} = \cancel{1.98 \times 10^{-25}}$$

or, $\lambda_c = \dfrac{1.98 \times 10^{-25}}{2.84 \times 1.6 \times 10^{-19}} = 4.35 \times 10^{-7}$ m

2a) What do you mean by ionization potential? What does it signifies that ionization potential for H-atom is 13.6 eV?

→ The minimum potential required to eject / knock out the electron completly from the atom is called ionization potential.

Ionization potential for H-atom is 13.6 eV means 13.6 V potential is required to knock out electron from an atom.

b) The ground state of the electron in the H-atom may be represented by the energy −13.6 eV and the First two excited states −3.4 eV and −1.5 eV, respectively as shown in Fig. On a scale in which an electron completely free of the atom is at zero energy. use this line to calculate the wavelength of three lines in the emission spectrum of hydrogen.

→ Given that

$E_1 = -13.6$ eV

$E_2 = -3.4$ eV

$E_3 = -1.5$ eV.

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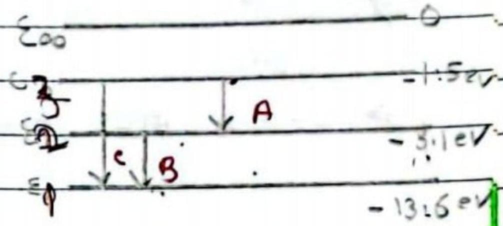
wavelength of A is given by



$\Delta E = \varepsilon_3 - \varepsilon_2$

$h \times F = -1.5 - (-3.4)$ ev

$\frac{h \times c}{\lambda} = 1.9$ ev

or, $\frac{1}{\lambda} = \frac{1.9 \times 1.6 \times 10^{-19}}{hc} = \frac{3.04 \times 10^{-19}}{6.6 \times 10^{-34} \times 3 \times 10^{8}}$

or, $\lambda = 1.53 \times 10^{-7}$ m

Wavelength of B is given by

$\lambda = \frac{h \times c}{(\varepsilon_2 - \varepsilon_1) \times 1.6 \times 10^{-19}} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{10.5 \times 1.6 \times 10^{-19}}$

$= 1.17 \times 10^{-7}$ m

c i) Name the shortest and longest wavelength in the given transitions.

→ Shortest wavelength = ε_2 to ε_0 = $\lambda_3 = 1.02 \times 10^{-7}$ m

ii) Determine the energy of photon emitted in transition from 1st excited state to ground state.

→ $\Delta E = \varepsilon_1 - \varepsilon_0$

$= -3.1 - (-13.6)$ eV

$= 10.5$ ev

3a) What is the significance of negative energy of electron in the stationary orbits?

→ It signifies that

b) Figure shows three energy levels for the atoms of a particular substance, the energies being in eV. A beam of electron passing throug this substance may excite electron from the various energy levels. What is the minimum p.d through which the electron must be accelerated from rest to cause any excitation between two of these levels. At what speed would these electrons be travelling.

1 ——— 0

2 ——— -2

3 ——— -12

→ Solution.

Ionization potential = ? (V_i)

First $\Delta E = \mathcal{E}_2 - \mathcal{E}_1$

$eV_i = \cancel{2\,eV}\ -2 - (-12)\,eV$

$eV_i = \cancel{2V\ 12}\ 10\,eV$

or, $V_i = 10V$ ✗

$K.E = eV$

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

9.1×

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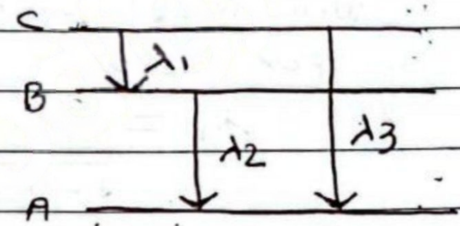
Q) A certain atom has energy level A, B and C corresponding to the increasing values of energies. i.e $\varepsilon_A < \varepsilon_B < \varepsilon_C$. If λ_1, λ_2 and λ_3 are the wavelength of radiation corresponding to the transition C to B, B to A and C to A respectively. Then

a) Which of the wavelength is shortest?

b) Which of the wavelength is longest?

c) Find λ_3 in terms of λ_1 and λ_2.

$$[E \propto 1/\lambda]$$



a⇒ λ_3 is the shortest wavelength.

b⇒ λ_2 is the longest wavelength.

c⇒ we know,

$$E_C - \varepsilon_A = (\varepsilon_C - \varepsilon_B) + (\varepsilon_B - \varepsilon_A)$$

$$\frac{h \times c}{\lambda_3} = \frac{h \times c}{\lambda_1} + \frac{h \times c}{\lambda_2} \Rightarrow \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\text{or, } \lambda_3 = \frac{\lambda_2 \cdot \lambda_1}{\lambda_2 + \lambda_1}$$

Q) If an electron in an hydrogen atom jumps from n=1 to n=4 orbit. What will be the maximum number of photoelectrons emitted?

→ Solution.

$$\text{we have } \Delta E = 13.6 \left(\frac{1}{(n_1)^2} - \frac{1}{(n_2)^2} \right)$$

$$\text{or, } hf = 13.6 \times \left(\frac{1}{(1)^2} - \frac{1}{(4)^2} \right)$$

$$\text{or, } hf = 13.6 \left(\frac{16-1}{16} \right) = 34\text{ev.}$$

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V. Good.
Keep it up.