Atomic Structure

Representation of atom

$_{Z}X^{A}$

Z = atomic no. (Total no. of proton present in an atom)
└ (Total no. of electron present in neutral atom)
A → atomic mass
└ (total no. of proton + total no. of neutron)
X → atom.

Isotope:- atomic no. same but different mass no.

→ same Z but different A.

e.g. $_1H^1$ protium n=0 ; $_1H^2$ deuterium n=1 ; $_1H^3$ Tritium n=2.

$_6C^{12}$ $_6C^{14}$

$_8O^{16}$ $_8O^{18}$

Isobar:- Same mass no. but different atomic no.

e.g. $_{18}Ar^{40}$ $_{20}Ca^{40}$

Isoelectronic species → Atom, molecules or ions having same no of electron.

e.g. Na^+ , O^{--} , F^-
10e 10e 10e.

Q. Which of the following species are isoelectronic with $[Ni(CO)_4]$.

$(28+(6+8)\times4) = 84e$.

(a) $Fe(CO)_5$: $26+(8+6)\times5 = 96e$.
(b) $[Co(CO)_4]$: $27+(8+6)\times4+1 = 84e$
(c) $[V(CO)_6]$: $23+14\times6 = 107e$.
(d) None.

Isosters:- species having same no. of electron and same no. of atom.

e.g. CO_2 & N_2O.
6+16=22 14+8=22.

Isodiaphers:- (n-p) same.

$_{15}P^{31}$: n = 31-15 = 16. n-p=1
$_{17}Cl^{35}$: n = 18 n-p=1
$_{11}Na^{23}$: n = 12 n-p=1

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Isotone - same no. of neutron.

$_{12}Mg^{24}$ and $_{11}Na^{23}$

n = 12 n = 12

Q. Which of the following are isosters?

(a) N_2O, CO (b) N_2, CO_2 (c) $B_3N_3H_6$, C_6H_6 (d) HF, Ne.

(12) (12)

15+2+6 = 42e 6×6+6×1 = 42e

Q. Which is isodiaphers?

(a) $_{15}P^{31}$, $_{8}O^{18}$ (b) $_{6}C^{14}$, $_{8}O^{16}$ (n-p) - same.

(c) $_{11}Na^{23}$, $_{13}Al^{27}$ (d) $_{24}Cr^{50}$, $_{19}K^{39}$

n-p = (2) n-p = (2)

Atomic Model

(I) J.J. Thompson Model

→ A/c to this model, atom is a +vely charged sphere in which -ve charge is uniformly distributed.

– compared to 'watermelon'.

→ pulp = +ve charge & seed ⇒ -ve charge.

– plum pudding model. (रिवर्स model).

• Drawback

(i) An important drawback is, – mass is considered to be evenly spread over the atom.

(ii) It is a static model. It does not reflect the movement of e⁻.

(iii) It couldn't explain the stability of an atom.

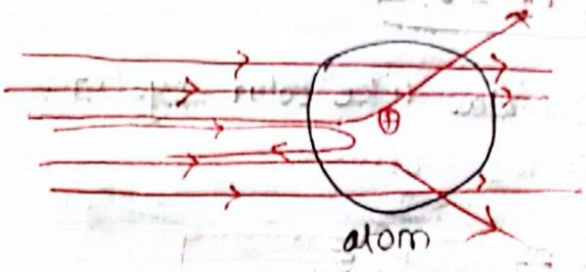
(iv) No चर्चा of neutron.

(2) Rutherford model / Gold foil exp / α-particle scattering experiment

→ α-particle → He nucleus. or He^{++}.

He-atom	α-particle
$2He^{+2} \xrightarrow{-2e^-}$	He^{+2}
$e^- = 2$	$e = 0$
$p = 2$	$p = 2$
$n = 2$	$n = 2$.

→



Observation

- Max. α-particle (≈ 99%) no deflection which means major part of atom is hollow.
- Few α-particle which were nearer to the centre get deflected from the path making some angle.
- Very few (1 in 20,000) α-particle which strikes the centre retraces the path

Conclusion

- Atom has 2 part.
  1. Nuclear part
  2. Extranuclear part
  - Nuclear part is responsible for mass whereas extranuclear part is responsible for size / volume.
- Max. part of an atom is empty.
- At the centre of an atom, a small +vely charged sphere is +nt. i.e. nucleus discovered by rutherford.
- All mass of an atom is concentrated in the nucleus.

Radius of nucleus

$$R = (1.25 \times 10^{-13}) A^{1/3} \text{ cm}.$$

R

$A \rightarrow$ atomic mass no.

$R \propto A^{1/3}$

$\therefore R = R_0 A^{1/3}$ cm.

$$\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

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The order of radius of nucleus is 10^{-13} cm or 10^{-15} m or 1 Fermi

Q. Mass no. of 2 different element are 27 and 8 respectively. Then find out ratio of their radius.

$$\frac{r_1}{r_2} = \left(\frac{A_1}{A_2}\right)^{1/3}$$

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

$$\therefore \boxed{r_1 : r_2 = 3 : 2}$$

→ e^- revolve around the nucleus like solar system.

→ $\frac{R_{atom}}{R_{nucleus}} = \frac{10^{-10}\,m.}{10^{-15}\,m.}$

$$\therefore \boxed{R_{atom} = 10^5 R_{nucleus}}$$

→ Density of nucleus → $\frac{m}{V}$.

$$= \frac{1.67 \times 10^{-27} \times A}{4/3\,\pi\,(1.25 \times 10^{-15}\,m)^3 (A^{1/3})^3}$$

$$\boxed{\rho_{nuc} = 10^{17}\ kg/m^3}$$

→ ρ of nucleus does not depend upon mass no. (A).

$V_{Atom} = 10^{15} V_{Nucleus}$.

Q. Find out the volume of nucleus of an atom having mass no. 64.

→ $A = 64$.

$$R = R_0 (A)^{1/3}$$

$$= 1.25 \times 10^{-15} \times (64)^{1/3}$$

$$= 5 \times 10^{-15}$$

$$V = \frac{4}{3}\pi R^3$$

$$= \frac{4}{3} \times \pi \times 5 \times 10^{-15}.$$

Q. Mass no. of 2 different elements are 27 and 64, Then find out ratio of their volume of nucleus.

$$V = \frac{4}{3}\pi R^3$$

$$= \frac{4}{3}\pi (R_0 A^{1/3})^3$$

$$\therefore V \propto A.$$

$$\therefore \frac{V_1}{V_2} = \frac{A_1}{A_2} = \frac{27}{64}.$$

* Drawback of Rutherford

(2) Maxwell theory → If a charge particle revolve in the presence of attractive field then it will emit energy in the form of electromagnetic wave.

– A/c to Rutherford, e^- is revolving around the +ve charge (in the presence of attractive field) then the energy will be decreasing continously & ultimately e^- will fall into the nucleus by following spiral path. Hence atom becomes unstable. But actually atom is stable.

→ If the energy of electron will be decreasing continously then spectrum should be continuous (but in reality, we get discontinuous spectrum).

(3) Bohrs Model :-

→ This model is based upon :
(i) Quatum theory
(ii) Classical law of physics.

→ Applicable for only single electron species, e.g. H, He^+, Li^{+2}, ...

Q. Bohr's model valid for :-

(a) H (b) He^+ (c) Li^{+2} (d) Na^{+10} (e) all

→ Bohr's model indicate particle nature of e^-.

→ Bohr's model is based on planck's quantum theory.

– A/c. to planck's theory, energy of radiation is $\propto$ frequency.

$$E \propto f$$

$$E = hf$$

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

h → planck's constant
$= 6.6 \times 10^{-34}$ J s.
$= 6.6 \times 10^{-27}$ ergs.

c → 3×10^8 m/s.

f → Freq. of photon

λ → wavelength of photon.

Q. Find out the ratio of energy of two different radiation having wavelength 10^{-10} m and 2×10^{-10} m.

→ $E \propto \frac{1}{\lambda}$ $\quad \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$

$= \frac{2 \times 10^{-10}}{10^{-10}} = 2.$

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→ Postulates

(i) A/c to Bohr, e^- revolve around the nucleus in fixed circular orbit.

(ii) e^- revolve only in those orbit whose angular momentum is an integral multiple of $h/2\pi$.

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

$n \rightarrow$ orbit no.

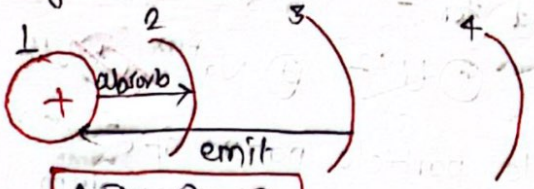
(iii) When electron revolve in fixed circular orbit then it will neither absorb nor emit the radiation.

Q. Angular momentum of e^- in 2nd orbit is:-

(a) $\frac{3h}{2\pi}$ (b) $\frac{h}{2\pi}$ (c) $\frac{h}{\pi}$ (d) $\frac{2h}{\lambda}$

$n = 2$. $\therefore mvr = \frac{2h}{2\pi} = h/2\pi$

(iv) When electron show transition from lower energy level to higher energy level then it will absorb the ration and when electron show transition from higher to lower level then it will emit the radiation



$$\boxed{\Delta E = E_2 - E_1}$$

(v) Absorbtion and emission is in the form of fix energy bundle i.e. known as photon and energy of photon.

$$\boxed{\Delta E = hF = \frac{hc}{\lambda}}$$

(vi) Energy change during transition is always:

$$\boxed{\Delta E = E_{high} - E_{lower}}$$

absorption	emission
$n = 1$, $n_2 = 2$.	$n_1 = 2$ & $n_2 = 1$.

Q. Energy of one mole of photon is equal to :-

(a) $N_A hF$ (b) hF (c) $\frac{hF}{N_A}$ (d) $2N_A F$

avagardo no.

Mathematical analysis of Bohr's model

Radius =

$$r = \frac{0.53 n^2}{Z} \text{ A°}$$

$r \propto n^2$

$n \propto \frac{1}{Z}$

e.g. for H atom

$Z = 1$

$r_H = 0.53 n^2$ A°

if $n = 1$: $(r_1)_H = 0.53 \times (1)^2$

$(r_1)_H = 0.53$ A°

If $n_2 = 2$, $(r_2)_H = 0.53 \times 2^2$ A°

$\therefore r_n = n^2 (r_1)_H$

For He^+ atom

$r = 0.53 \times \frac{n^2}{Z}$

$n = 1$, $r_1 = \frac{0.53}{2} \times (1)^2 = \frac{0.53}{2}$

$n = 4$, $r_4 = \frac{0.53}{2} \times (4)^2$

For Li^{++}

$r = 0.53 \times \frac{n^2}{3}$

Q. $I_n = n^2 (r_1)$ is valid for:—

(a) H $r_1 = 0.53$ (b) He^+ $r_2 = \frac{0.53}{2}$ (c) Li^{++} $r_3 = \frac{0.53}{3}$ (d) All

Q. Four hydrogen atom, $r_3 = 9 - r_1$, $r_2 = 4 - r_1$, $r_4 = 16 - r_1$.

(a) 3, 2, 4 (b) 4, 3, 2 (c) 6, 9, 4, (d) 9, 4, 16

Q. Radius of 1st bohr orbit of Hydrogen atom is 0.53 A°. Calculate the radius of 3rd excited state.

$n = 4$.

$r_4 = 0.53 \times 4^2$

$= 8.4$ A°

Q. Calculate the distance between 2nd & 3rd Bohr orbit of the atom.

→ $r_2 = 2^2 r_1$

$r_3 = 3^2 r_1$

$\therefore r_3 - r_2 = 3^2 r_1 - 2^2 r_1$

$= r_1 (9 - 4)$

$r_3 - r_2 = 5 r_1$

Trick 3 & 2 → 3+2=5 & 6+5 = 11.

Q. Find out the ratio of distance between 8th orbit & 9th orbit to 3rd orbit & 4th orbit?

→ $\frac{8+9}{3+4} = \frac{17}{7} = 17:7$

Q. Radius of 1st Bohr orbit of H-atom is 0.52×10^{-8} cm. Calculate the radius of 1st orbit of He^+?

Sol → $r_{(He^+)} = \frac{0.52 \times 10^{-8}}{2} = 0.26 \times 10^{-8}$ cm.

Q. 2nd orbit of Li^{+2} to 3rd orbit of He^+.

→ $\frac{r_1}{r_2} = \frac{\frac{0.53 \times 4}{3}}{\frac{0.53 \times 9}{2}} = \frac{4 \times 2}{9 \times 3} = \frac{8}{27}$

Q. If the radius of 3rd orbit of Hydrogen is x. Then the radius of same orbit of Li^{++} will be:-

(a) x (b) $3x$ (c) $x/3$ (d) $x/4$

$r = 0.53 \times \frac{n^2}{Z}$ A°

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

$\frac{r_1}{r_2} = \frac{n_1^2}{n_2^2} \times \frac{Z_2}{Z_1}$ (orbit same)

$= 3/1$

$\therefore r_2 = x/3$

Q. Radius of 4th orbit of H-atom:-

$r_4 = r_1^2 \times n^2 = 0.53 \times 16$

$= 8.54$ A°

Q. Ratio of $r_1H : r_2H : r_3H \rightarrow 1:4:9$.

Q. Ratio of $r_1(H) : r_2(He^+) : r_3(Li^{++}) \Rightarrow \frac{1^2}{1} : \frac{2^2}{2} : \frac{3^2}{3} = 1:2:3$

Q. $r_1(H) : r_1(He^+) : r_1(Li^{++}) \rightarrow \frac{1}{1} : \frac{1}{2} : \frac{1}{3}$.

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Velocity of electron in Bohr orbit

$$v = 2.18 \times 10^8 \frac{Z}{n} \text{ cm/s}$$

$$\boxed{v = 2.18 \times 10^6 \frac{Z}{n} \text{ cm/s}}$$

$v \propto Z$, $v \propto \frac{1}{n}$.

Q. Find the ratio of velocity of e⁻ in 2nd orbit of Li^{+2} to 3rd orbit of Be^{+3}?

→ $$\frac{v_1}{v_2} = \frac{\frac{Z_1}{n_1}}{\frac{Z_2}{n_2}} = \frac{\frac{3}{2}}{\frac{4}{3}} = 3/2 \times 3/4 = \frac{9}{8}$$

Q. If velocity of electron in 2nd excited state ($n=3$) of He^+ ion is x. Then find the velocity of e⁻ in 2nd orbit of Be^{+3}?

→ $$\frac{v_1}{v_2} = \frac{x}{v_2} = \frac{\frac{Z_1}{n_1}}{\frac{Z_2}{n_2}} = \frac{2/3}{4/2} = \frac{1}{3}$$

$$\therefore \frac{x}{v_2} = \frac{1}{3}$$

$$\therefore \boxed{v_2 = 3x}$$

Energy

$$\boxed{T.E = P.E + K.E}$$

$$\boxed{\begin{aligned} P.E &= -x \\ K.E &= +x/2 \\ T.E &= -x/2 \end{aligned}}$$

$$\boxed{x = \frac{KZe^2}{r}}$$

$$P.E = \frac{-KZe^2}{r}, \quad K.E = \frac{KZe^2}{2r}, \quad T.E = \frac{-KZe^2}{2r}$$

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

Q. $$\frac{P.E}{K.E} = \frac{-x}{+x/2} = -2.$$

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$E_T = -13.6 \frac{Z^2}{n^2}$ eV/atom

$(E_T)_H = -\frac{13.6}{n^2}$ eV/atom, $Z = 1$

$n = 1$, $(E_1)_H = -13.6$ eV/atom

$n = 2$, $(E_2)_H = -\frac{13.6}{4} = -3.4$ eV/atom

$n = 3$, $(E_3)_H = -1.51$ eV/atom

$n = 4$, $(E_4)_H = -0.85$ eV/atom

$n = 5$, $(E_5)_H = -0.54$ eV/atom.

→ $(T.E)_{\text{any species}} = (T.E)_H \times Z^2$

Q. $(T.E)_3$ for He^+ = ?

$= -1.51 \times 2^2$

$= -6.04$ eV

Q. The P.E of an electron in H-atom is -3.02 eV. And :-

(a) K.E (b) T.E (c) orbit (d) Radius.

Sol - P.E = -3.02 eV

$K.E = \frac{3.02}{2} = 1.51$ eV

$T.E = -K.E = -1.51$ eV

$\therefore (TE) = -1.51$ eV

$\therefore n = 3.$

$r_3 = 0.53 \times n^2$

$r_3 = 0.53 \times 3^2$ A°

$= 4.77$ A°.

Q. K.E of an electron in atom is 3.4eV. Find :-

(a) P.E (b) T.E (c) orbit (d) radius

→ K.E = 3.4eV

P.E = -2K.E

= -6.8 eV.

T.E = -K.E

= -3.4eV.

∴ n = 2, $r_1 = 0.53 \times 2^2$ Å

→ $(\Delta E)_{any species} = (\Delta E)_H \times Z^2$

Q. $E_2 - E_1$ For He^+ = ?

→ For H

$E_2 = -3.4eV$

$E_1 = -13.6$.

∴ $E_2 - E_1 = 10.2$ eV

∴ $(E_2 - E_1)_{He} = (E_2 - E_1)_H \times Z^2$

$= 10.2 \times 2^2$

$= 40.8$ eV

Q. $E_3 - E_2$ For Li^{++} = ?

→ for H,

$E_3 - E_2 = -1.51 - (-3.4)$

$= 1.89$ eV.

∴ $(E_3 - E_2)_{Li^{++}} = (E_3 - E_2)_H \times 3^2$

$= 1.89 \times 9$

$= 17.01$ eV.

Q. Find out P.E in 2nd excited state of He^+.

(n = 3.)

∴ $(T.E)_{He^+} = (T.E)_H \times Z^2$

$= -1.51 \times 4 = -6.04$ eV.

∴ P.E = 2T.E

= -12.08 eV.

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Q. $E_2 - E_1 = 1210$ eV. Then find out the value of z?

→ $(\Delta E) = (\Delta E)_H \times z^2$ $\qquad (E_2 - E_1)_H = (12.1)$

$1210 = 12.1 \times z^2$

$\therefore z = 10.$

Q) Find out $(K.E)_5$ for Ne^{+9}. (n = 5)

$(T.E)_5 = (T.E)_H \times z^2$

$= -0.54 \times 10^2$

$= -54$ eV.

$\therefore$ K.E = 54 eV = −T.E

P.E = −2T.E = −108 eV.

Ionisation energy

- It is the minimum amount of energy which is required to eject an electron from ground state to infinite.

$(I.E)_H = 0 - (-13.6)$

$= 13.6$ eV.

Separation energy

→ It is the minimum amount of energy which is required to escape electron from any excited state (n≠1) to infinite.

Excitation energy

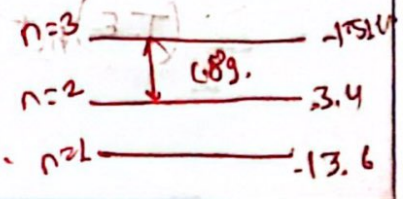
→ It is the minimum amount of energy which is required to eject electron from one level to another.

n=1 to n=2 & n=2 to n=3.

Q. If I.E/I.P of H atom is x eV. Then calculate the required energy from 2nd to 3rd orbit. I.E = 13.6 eV.

(a) x (b) 3/4 (c) 5x/36 (d) 7/12.

$\frac{5x}{36} = \frac{5 \times 13.6}{36}$ = 1.89 eV.



Q. Ionization potential of H-atom is 13.6 eV. Calculate I.P of He^+ & Li^{++}

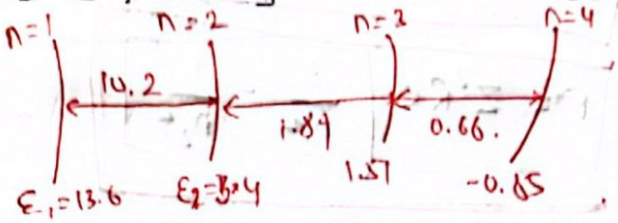
→ $(I.E) = (I.E)_H \times Z^2$

- $(I.E)_{He^+} = 13.6 \times 4$
- $(I.E)_{Li^{++}} = 13.6 \times 9$

Q. In following, which is the correct sequence of energy difference?

(a) $\Delta E_1 > \Delta E_2 > \Delta E_1$ (b) $\Delta E_1 < \Delta E_2 < \Delta E_3$

(c) $\Delta E_1 = \Delta E_2 = \Delta E_3$ (d) None.



Q. In H-atom, P.E of e^- is -6.8 eV. Then e^- is present in which excited state.?

Sol → $T.E = \frac{P.E}{2} = \frac{-6.8}{2} = -3.4$ eV.

$\therefore n = 2$.

$\therefore$ excited state = 3.

→ $(T.E)_{any} = (T.E)_H \times Z^2$

$(\Delta E)_{any} = (\Delta E)_H \times Z^2$

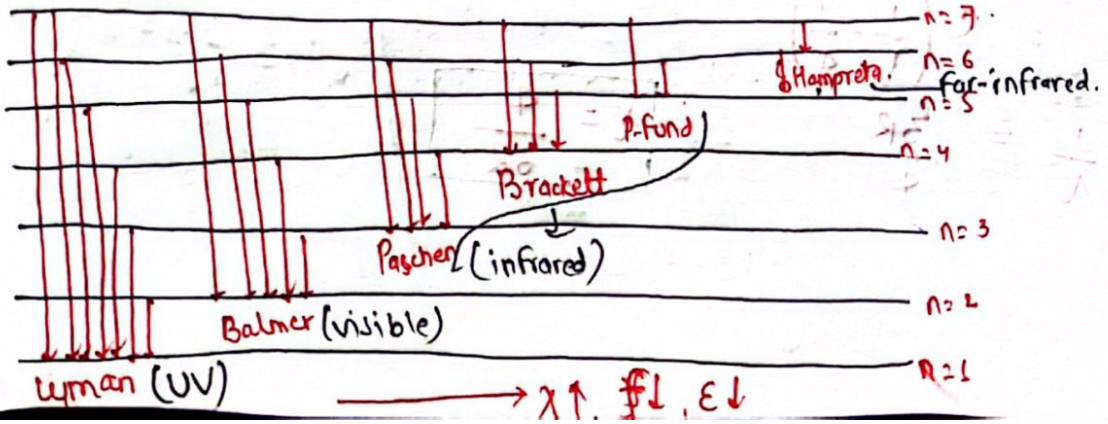
$(I.E)_{any} = (I.E)_H \times Z^2$

Hydrogen Spectrum

→ Emission spectrum

→ Line spectrum.

→



Rydberg formula

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

- $\bar{\nu}$ → wave no.
- λ → wavelength
- R → Rydberg const.
  - $= 1.09 \times 10^7\ m^{-1}$
  - $= 1.09 \times 10^5\ cm^{-1}$

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

$F = \frac{c}{\lambda}$

$\frac{1}{\lambda} = \frac{F}{c}$.

$\therefore \boxed{\frac{F}{c} = R Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$

$\therefore \boxed{F = Z^2 R c \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]}$

(1) Lyman series

$n_1 = 1, \quad n_2 = 2, 3, 4, \ldots$

- $n_1 = 1$ & $n_2 = 2$ → 1st Lyman line
- $n_1 = 1$ & $n_2 = 3$ → 2nd Lyman line
- $n_1 = 1$ & $n_2 = 4$ → 3rd " "
- $n_1 = 1$ & $n_2 = \infty$ → Last Lyman line

- U.V. region.

Q. An electron show transition according to 1st Lyman line then find its λ.

($n_1 = 1$ & $n_2 = 2$)

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

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

$\frac{1}{\lambda} = \frac{3R}{4}$ $\therefore \boxed{\lambda = \frac{4}{3R}}$

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② Balmer series

$n_1 = 2 \quad n_2 = 3, 4, 5, 6, \ldots$

- $n_1 = 2$ & $n_2 = 3$ → first balmer line (α-Balmer).
- $n_1 = 2$ & $n_2 = 4$ → 2nd " " (β - ")
- present in visible region.

Q. An electron show transition according to 1st Balmer series. Then find frequency of transition.
└ $n_1 = 2, n_2 = 3$.

→ $$F = RC\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

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

$$\boxed{F = \frac{5CR}{36}}$$

③ Paschen series

$n_1 = 3, \quad n_2 = 4, 5, 6, \ldots$

Q. An electron show transition alc to 1st paschen line, then the energy of radiation is:
└ $n_1 = 3$ & $n_2 = 4$.

→ $$E = \frac{hc}{\lambda} = hc \times \frac{1}{\lambda}$$

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

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

$$\boxed{E = \frac{7hcR}{144}}$$

④ Brackett series

$n_1 = 4, \quad n_2 = 5, 6, 7, \ldots$

* Max. wavelength = P-fund
* Min. wavelength = Lyman
* Max. frequency = Lyman
* Min. frequency = P-fund.
* Max. energy = Lyman
* Min. energy = P-fund.

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Imp. Point

Last line, ending line, Marginal line, Series limit } $\rightarrow n_2 = \infty$

First line, starting line, initial line } $\rightarrow n_2 = (n_1 + 1)$.

Q. Find the wave no. for last line of Balmer series of Li^{+2}?

→ $n_1 = 2, \quad n_2 = \infty$.

$$\bar{\nu} = R z^2 \left[\frac{1}{2^2} - \frac{1}{\infty^2}\right]$$

$$= R/4 \times 3^2 \qquad (Li^{++})$$

$$= R/4 \times 9$$

$$\bar{\nu} = \frac{9}{4} R. = \frac{1}{\lambda}.$$

$\bar{\nu}$ ← wave no.

* Maximum no. of spectral lines between 2 levels

No. of spectral lines $= \frac{\Delta n (\Delta n + 1)}{2}$ $\quad (\Delta n = n_2 - n_1)$.

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

but from higher to ground → $\frac{n(n-1)}{2}$

Trick

6 to 1 → $(6-1) = 5 + 4 + 3 + 2 + 1 = 15$.
(Ly. Bal. Bra. Pa. P-fu.)

6 to 3 ⇒ $(6-3) = 3 + 2 + 1 = 6$.

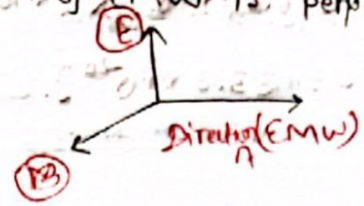
5 to 1 → $(5-1) \Rightarrow 4 + 3 + 2 + 1 = 10$.
(Ly. Bal. Pashen. Bracket.)

6 to 2 → $4 + 3 + 2 + 1 = 10$.
(Ly. Bal. Pa. Pfund.)

6 to 3 → $3 + 2 + 1 = 6$.
(Pashen. Bracket. P-fund.)

Electromagnetic Wave

→ It contains both electric field and magnetic field.
→ vel. of EMW = vel. of light = 3×10^8 m/s.
→ Donot require any medium for propagation.
→ Direction of EMW is perpendicular to E & B both.



@ Ra M I visited u at Xavier's Graduation Ceremony

Radio waves, micro wave, infra red, visible ray, U.V ray, X-ray, Gamma rays, Cosmic ray

$F\uparrow, E\uparrow, \lambda\downarrow$

V I B G Y O R → R O Y G B I V

$F\uparrow, E\uparrow, \lambda\downarrow$

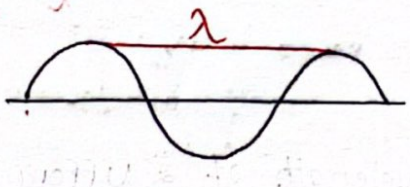
* Properties

① **Frequency:-**

$F = \frac{c}{\lambda}$ unit → sec^{-1} or Hertz.

② **Wavelength:-**

$\lambda = \frac{c}{F}$ unit → m/cm/nm/Å;



③ **Waveno ($\bar{\nu}$)**

Reciprocal of wavelength.

$\bar{\nu} = \frac{1}{\lambda}$ ⇒ unit → $m^{-1}/cm^{-1}/mm^{-1}$.

④ **Energy of photon**

$E = hF$

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

For n photon,

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

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Wavelength of radiation is 6000 A°. Then find its frequency & energy.

→ $\lambda = 6000\ A°$

$$f = \frac{c}{\lambda} = \frac{3.8\times10^{6}}{6000\times10^{-10}}$$

$$= \frac{3.8\times10^{6}}{6\times10^{-7}}$$

$$= 6.5\times10^{4}\ Hz.$$

$$E = hf$$

$$= 6.64\times10^{-34}\times5\times10^{14}$$

$$= 33.3\times10^{-20}\ J.$$

Q. The wave no. of a beam of light is 400 cm^{-1}. Calculate the wavelength in terms of nanometer. Also find its frequency.

→ $\bar{\nu} = 400\ cm^{-1}$

$$\lambda = \frac{1}{\bar{\nu}} = \frac{1}{400\times10^{-2}}\ m$$

$$= \frac{1}{4} = 0.25\ m$$

$$= 0.25\times10^{-9}\ nm.$$

$$= 2.5\times10^{-8}\ nm = 2.5\times10^{-10}\ A°$$

$$f = \frac{c}{\lambda} = \frac{3\times10^{8}}{2.5\times10^{-10}} = \frac{3}{2.5}\times10^{18}\ Hz.$$

$$\Rightarrow 1.2\times10^{6}\ Hz.$$

Q. Wavelength of 2 different radiation are 600 nm & 1200 nm. Then their ratio of their energy is :-

(a) 1/3 (b) 1/2 (c) 3/1 (d) 2/1

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

$$\frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{1200}{400} = 3:1.$$

Q. Frequency of radiation is $5\times10^{16}\ Hz$. Find wave no.

→ $$\bar{\nu} = \frac{1}{\lambda} = \frac{f}{c} = \frac{5\times10^{16}}{3\times10^{8}} = 1.6\times10^{8}\ m^{-1}.$$

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Q. A 25watt bulb emit radiation of wavelength 0.66 μm. Find out the no. of quanta in 1 sec.

→ $\lambda = 0.66\,\mu m$
$= 0.66 \times 10^{-6}\,m$
$= 6.6 \times 10^{-7}\,m$

$P = 25\,watt$

$\frac{E}{T=1} = 25\,watt$

$\frac{nhc\lambda}{\lambda} = 25$

$25 = \frac{n \times 6.6 \times 10^{-34} \times 3 \times 10^{8}}{0.66 \times 10^{-6}}$

$\therefore \boxed{n = 8.3 \times 10^{21}}$ m.

Q. Which of the following angular momentum does not show presence of e^- in an orbit?

(a) $0.5\frac{h}{\pi}$ (b) $2.5\frac{h}{\pi}$ (c) $3.5\frac{h}{2\pi}$ (d) $\frac{5h}{\pi}$

$\frac{nh}{2\pi}$ $n=1$ $n=5$ $n=3.5$ $n=10$

Q. In H-atom, electron jump from 6th energy level to 1st energy level in single step. Find max no. of spectral line.

(a) 1 (b) 9 (c) 15 (d) 2.

Q. In H-atom, electron jump from 6th energy level to 1st energy level. Find max. no. of spectral line.

(a) 1 (b) 9 (c) 15 (d) 2.

→ $(6-1) = 5+4+3+2+1 = 15$.

Q. Higher orbit (n) वाटा G.S मा आओ → 21 वटा spectral line. So, n=?

$21 = \frac{n(n-1)}{2}$

$42 = n^2 - n$

$\therefore \boxed{n = 7}$

* Drawback of Bohr's Model

(1) Couldn't explain the spectrum of multiple electron species.

(2) When hydrogen spectrum was studied by high resolution spectroscopy then one line was found to be split upto no. of fine lines means one energy level was further divided into further sub-energy level.

(3) Splitting of one line into no. of lines in presence of electric field is known as → Stark effect & in +nce of magnetic field is Zeeman effect.

(4) Couldn't explain about $mvr = \frac{nh}{2\pi}$.

(5) Bohr related with particle nature of e^-. He couldn't explain the wave nature.

Wave Mechanical Model

• De-Broglie equation

→ De-Broglie model is applicable for small particles in which energy is due to its speed (K.E).

→ Alc to De-Broglie, electron indicate the dual nature when it is in rest condition it is a particle but when it is in motion it is a wave.

→ When small particles moves with very high velocity then they indicate the wave nature & related waves are called matter waves.

→ Wavelength of matter waves (De-broglie wavelength) is inversely proportional to its momentum.

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

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

h = plank's constant $[6.6 \times 10^{-34}\ J/s]$.
m ⇒ mass of particle
v ⇒ vel. of "

$$\therefore \frac{\lambda_A}{\lambda_B} = \frac{p_B}{p_A} = \frac{m_B v_B}{m_A v_A}$$

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Q. Wavelength of particle A is 5×10^{-8} m then find out the wavelength of particle B, while momentum of particle B is half of A.

(a) 10^{-9} m (b) 10^{-7} m (c) 10^{-5} m (d) 10^{-6} m

$$\lambda = \frac{h}{p} = \frac{h}{mv} \quad \left(\because p_B = \frac{1}{2} p_A\right).$$

$$\frac{\lambda_A}{\lambda_B} = \frac{p_B}{p_A}$$

$$\frac{5 \times 10^{-8}}{\lambda_B} = \frac{1}{2} \quad \therefore \lambda_B = 10^{-7}.$$

Q. Wavelength of particle A is 1 A°, then calculate the λ of B, while mass of particle B is 25% of A & velocity of B is 75% of A.

(a) 10.66 A° (b) 5.33 A° (c) 2.67 A° (d) 8.33 A°

$$\frac{\lambda_A}{\lambda_B} = \frac{m_B v_B}{m_A v_A} \qquad \left(\frac{m_B}{m_A}\right) = \frac{1}{4}, \left(\frac{v_B}{v_A}\right) = \frac{3}{4}$$

$$\frac{\lambda_A}{\lambda_B} = \frac{1}{4} \times \frac{3}{4}$$

$$\lambda_B = \frac{16}{3} = 5.33 \text{ A°}$$

Q. Velocity of α-particle is 3×10^3 m/s, Find its wavelength;—

(a) 0.68 A° (b) 0.34 A° (c) 0.17 A° (d) 1.02 A°

Relation between De-Broglie wavelength & K.E

$$\boxed{\lambda = \frac{h}{\sqrt{2mkE}}}$$

Q. K.E of e^- is 4.55×10^{-25} J. Calculate De Broglie wavelength.

→ $(m)_e = 9.1 \times 10^{-31}$ kg, $h = 6.6 \times 10^{-34}$ Js.

$$\lambda = \frac{h}{\sqrt{2m\,K.E}} = \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 4.55 \times 10^{-25} \times 9.1 \times 10^{-31}}}$$

$$= 7.3 \times 10^{-7} \text{ m}.$$

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

De-Broglie in Form of T

$$K.E = \frac{3}{2}kT$$

$$\lambda = \frac{h}{\sqrt{2mK.E}} = \frac{h}{\sqrt{2m \times \frac{3}{2}kT}} = \frac{h}{\sqrt{3mkT}}$$

$K \rightarrow$ Boltzman constant
$= 1.33 \times 10^{-23}$.

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{h}{\sqrt{2mK.E}} = \frac{h}{\sqrt{2mqV}} = \frac{h}{\sqrt{3mkT}}$$

Q. H_2 & O_2 are accelerated at 27°C & 427°C respectively. Then find out ratio of De-Broglie wavelength of H_2 & O_2.

(a) $\frac{4\sqrt{7}}{\sqrt{3}}$ (b) $\frac{3\sqrt{7}}{\sqrt{3}}$ (c) $\frac{\sqrt{12}}{\sqrt{3}}$ (d) $\frac{3\sqrt{7}}{\sqrt{4}}$

$$\lambda \propto \frac{1}{\sqrt{T \times m}}$$

$$\frac{\lambda_{H_2}}{\lambda_{O_2}} = \sqrt{\frac{T_{O_2} M_{O_2}}{T_{H_2} m_{H_2}}} = \sqrt{\frac{700 \times 32}{2 \times 300}}$$

$$\frac{\lambda_{H_2}}{\lambda_{O_2}} = \frac{4\sqrt{7}}{\sqrt{3}}$$

Heisenberg Uncertainty Principle

→ A/c to Heisenberg, it is not possible to calculate the exact position & momentum (velocity) of small moving particle at a time.

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

Δx → uncertainity in position

Δp → uncertainity in ~~velocity~~ momentum.

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

Δv → uncertainity in velocity

- If $\Delta x = 0$, then Δp and Δv will be ∞ and vice-versa.

Q. Uncertainity in position of e^- is zero, then find out uncertainity in its momentum.

(a) 0 (b) 1 ~~(c) ∞~~ (d) $\frac{h}{4\pi}$.

$\Delta x = 0$.

$\therefore \Delta p = \frac{h}{4\pi \times 0} = \infty$.

Q. An uncertainity in position and ~~momentum, uncertainity~~ is same, find the uncertainity in its velocity.

(a) $\frac{1}{2m}\sqrt{\frac{\pi}{h}}$ ~~(b)~~ $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$ (c) $\frac{1}{m}\sqrt{\frac{h}{\pi}}$ (d) $\frac{1}{m^2}\sqrt{\frac{h}{\pi}}$

→ $\Delta x = \Delta p$.

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

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

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

$\Delta v = \frac{1}{2m}\sqrt{\frac{h}{\pi}}$.

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Q. Uncertainity in position of e^- is double then uncertainity in position of He-atom. If uncertainity in momentum of e^- is 32×10^5. Find uncertainity in momentum of He.

(a) 64×10^5 (b) 32×10^5 (c) 64×10^4 (d) 16×10^4

→

$$\frac{(\Delta x)_e \times (\Delta p)_e}{(\Delta x)_{He} \times (\Delta p)_{He}} = \frac{h/4\pi}{h/4\pi} = 1.$$

(2)

$$= \frac{2 \times 32 \times 10^5}{(\Delta p)_{He}} = 1.$$

$$\therefore (\Delta p)_{He} = 64 \times 10^5$$

Q. The velocity of electron is 3×10^4 cm/s, it is accurate upto 0.001%. Then find out the uncertainity in position?

→

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

$$\Delta v = 3 \times 10^4 \times \frac{0.001}{100}$$

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

$$= \frac{6.6 \times 10^{-27}}{4 \times 3.14 \times 9.1 \times 10^{-28} \times 0.3}$$ (CGS)

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