Modern physics

Photons

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

$$P = \frac{h}{\lambda} \quad , \text{ or } \quad P = \frac{E}{c}$$

where P = momentum of photon

E = Energy of photon

h is planck's constant

i.e $h = 6.62 \times 10^{-34}$ J-s

$$E = \frac{h\, c}{\lambda \text{ (in meter)}}$$

$h \to 6.62 \times 10^{-34}$ J-s, $c \to 3 \times 10^{8}$

- Mass of photon, $m = \dfrac{E}{c^2}$

- no. of photons striking per second :-

$$\frac{N}{t} = n = \frac{IA}{\left(\frac{hc}{\lambda}\right)} \quad , \quad \text{Power} = \left(\frac{N}{t}\right) \times \frac{hc}{\lambda}$$

Radiation Pressure

(Force exerted on a perfectly reflecting surface)

incident photon, $P = \frac{h}{\lambda}$

Reflected photon, $P = \frac{-h}{\lambda}$

- $\Delta P = \dfrac{2h}{\lambda}$
- $F = (\Delta P \times n)$
- Force $= \dfrac{2IA}{c}$
- Pressure $= \dfrac{F}{A} = \dfrac{2I}{c}$

- If a% absorbed
  r% is reflected.

then,

$$\text{Pressure} = a\left(\frac{I}{c}\right) + r\left(\frac{2I}{c}\right)$$

If 100% absorbing, then

$$\Delta P = \frac{h}{\lambda} \quad , \quad F = \Delta P \times n = \frac{IA}{c}$$

$$\text{Pressure}, P = \frac{I}{c}$$

Projection Area

$$F = P \times \text{Projection Area}$$

$$\Rightarrow F = \frac{I}{c} \times (\pi r^2)$$

100% absorbing

(*) Oblique Incidence

, normally, $n = \frac{I A \lambda}{hc}$

now, in oblique incidence →

$$\boxed{n = \frac{I \cos\theta \, A \lambda}{hc}}$$

100% absorbing

$f = \Delta P \times n$

$\Rightarrow f = \frac{h}{\lambda} \times \frac{I \cos\theta \, A \lambda}{hc}$

$$\boxed{\Rightarrow f = \frac{I \cos\theta \, A}{c}}$$

**

$$\boxed{\Rightarrow \text{Pressure} = \frac{I \cos^2\theta \, A}{c}}$$

** reflecting

$n = \frac{I \cos\theta \, A \lambda}{hc}$,

$$\boxed{\Rightarrow f = \frac{2 I \cos^2\theta \, A}{c}}$$

$$\boxed{\Rightarrow P = \frac{2 I \cos^2\theta}{c}}$$

(*) De-Broglie's Hypothesis

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

De-Broglie's wavelength

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

(*) Some important formula →

(i) $\lambda = \frac{h}{p}$ (ii) $\lambda = \frac{h}{\sqrt{2mK}}$ (iii) $\lambda = \frac{h}{\sqrt{2mqV}}$ {For accelerating charge particle}

(iv) $\lambda = \frac{h}{\sqrt{3mkT}}$ → Temp. in kelvin

k → Boltzman Constant

NOTE

$\lambda_e = \frac{12.27}{\sqrt{V}}$ Å → For electron

$\lambda_p = \frac{0.286}{\sqrt{V}}$ Å → for proton

$\lambda_\alpha = \frac{0.101}{\sqrt{V}}$ Å → for α particle

Atomic structure

Concept - 1 :-

$$\frac{K(Ze)e}{r^2} = \frac{mv^2}{r}$$

Concept - 2 :-

$$mvr = \frac{nh}{2\pi}, \; n = 1, 2, 3 \ldots$$

formula's for v and r

(i) $v \propto \frac{Z}{n}$ $\Rightarrow v = (2.2 \times 10^6) \times \frac{Z}{n}$ (m/s)

(ii) $r \propto \frac{n}{v}$, $r \propto \frac{n}{Z/n}$, $r \propto \frac{n^2}{Z}$

$$\Rightarrow r = \left(0.529 \times \frac{n^2}{Z}\right) \mathring{A}.$$

Some Energy related formula

(i) $K.E = -\frac{U}{2}$ — U → P.E

$\Rightarrow U = -2\,K.E$

(ii) $T.E = K.E + P.E$

$= K.E + (-2\,K.E)$

$\Rightarrow T.E = -K.E$

$$\boxed{T.E = +\frac{U}{2}}$$

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

$$U = 2\,K.E = -\frac{27.2\,Z^2}{n^2}\ \text{eV.}$$

Bohr's Theory of Hydrogen atom

Emission lines > Absorbtion lines spectrum

Ionization Energy

$$\boxed{I.E = \frac{13.6\,Z^2}{n^2}}$$

Frequency emitted Radiation

$$\frac{hc}{\lambda} = \left| 13.6 Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \right| eV$$

or, $$\frac{1}{\lambda} = \left| \underbrace{R Z^2}_{\text{Rydberg's constant}} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \right| eV$$

Rydberg's constant :

$R = 1.1 \times 10^7 \ m^{-1}$.

Lyman	Balmer	Paschen	Brackett	Pfund
$n=1$	$n=2$	$n=3$	$n=4$	$n=5$

$\Rightarrow$ Series limit , Lymann to Pfund (line)
$\Downarrow$
$\lambda_{min} / \nu_{max}$

1st line , Lymann to Balmer ($\lambda_{max} / \nu_{min}$)

* No. of spreectal lines :$\rightarrow$

$$\frac{n(n-1)}{2} = {}^nC_2$$

* Recoil velocity

$$\boxed{M v_{recoil} = \frac{h}{\lambda}} \Rightarrow v_{recoil} = \frac{h}{\lambda} \times \frac{1}{M}$$

$$= \frac{hc}{\lambda} \times \frac{1}{Mc}$$

$$\boxed{v_{recoil} = \frac{E_{photon}}{Mc}}$$

⊛ Photo electric effect :-

ϕ (Work function : minimum energy to eject e^-)

if $E_p < \phi$, No emission takes place

$E_p \geq \phi$, emission takes place

$\therefore$ $E_{photon} = E_{needed\ to\ remove} + K.E$ of that e^-

$$\boxed{\begin{aligned} \Rightarrow E_p &= \phi + K.E_{max} \\ \Rightarrow h\nu &= \phi + K.E_{max} \end{aligned}}$$

For emission, minimum frequency (ν_T) / threshold frequency

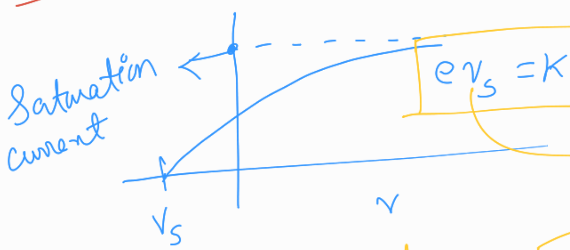
$$\underset{\text{min}}{h\nu_T} = \phi \quad , \quad \frac{hc}{\underset{\text{max}}{\lambda_T}} = \phi$$

Conversion

$\Rightarrow$ Joule to eV
Just divide by 1.6×10^{-19}

$\Rightarrow$ eV to Joule
Just multiply by 1.6×10^{-19}

Graph



$\boxed{eV_s = KE_{max}}$ $\rightarrow$ stopping potential

also, $\boxed{h\nu_p = \phi + eV_s}$

For constant ϕ,

$h\nu_p = \phi + eV_s$

greater the ν_p, greater the V_s (stopping potential)

NOTE :- Stopping potential (V_s) can't be +ve or 0.

X-Rays

$$\lambda_{min}\,(\text{in } \mathring{A}) = \frac{12400}{V_{acc}}$$

cutoff wavelength

Loss is in the form of heat and remaining are lossed in the form of photons.

And this loss are continuous bcz of loss of K.E

Remember

$E_p = 4.2\,eV$

$\phi = 3\,eV$

$V = 4\,eV$

$\therefore K.E = E_p - \phi$

$K.E = 1.2\,eV$

$$\therefore \lambda = \frac{12400}{4+1.2} = \frac{12400}{5.2}\,\mathring{A}$$

Characteristics X-Ray

K_α $\quad n=2$ to $n=1$

L_α $\quad n=3$ to $n=2$

K_β $\quad n=3$ to $n=1$

L_β $\quad n=4$ to $n=2$

Wavelength of K_α

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

NOTE $\boxed{b = 1 \text{ for } K_\alpha}$

Mosley's law

$$\sqrt{\nu} = a(z-b)$$

Now,
$$\frac{1}{\lambda_{K_\alpha}} = R(z-b)^2\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

$$\Rightarrow \frac{1}{\lambda_{K\alpha}} = \frac{c3}{4} R(z-b)^2 \Rightarrow \sqrt{\nu} = \sqrt{\frac{3Rc}{2}}\,(z-b)$$

On comparing on both sides,

$$\boxed{a = \sqrt{\frac{3RC}{4}}} \quad \boxed{\text{for } K_\alpha \text{ only}}$$

Diffraction of X-Ray

It takes place according to the Bragg's law.

Formula,
$$2d \sin\theta = n\lambda, \quad \theta \rightarrow \text{angle from surface}$$

or, $2d \sin(90 - i) = n\lambda,$

$\Rightarrow 2d \cos i = n\lambda.$

Note: If $\lambda > 2d$ diffraction is not possible i.e solution of Bragg's eqn is not possible.

Nucleus

$m_p = 1.672 \times 10^{-27}$ kg, $m_n = 1.674 \times 10^{-27}$ kg.

${}^{A}X_{Z} \Rightarrow$ A → Atomic mass number (no. of proton + no. of nuetrons)

Z → Atomic number (no. of protons = no. of electrons)

Types of nuclei

(a) Isotope → same 'Z'

(b) Isobar → same 'A'

(c) Isotone → same nuetron (A - Z)

Radius of Nucleus,

$$\boxed{R = R_0 (A)^{1/3}}, \text{ where } R_0 = 1.1 \times 10^{-15} \text{ m} = 1.1 \text{ fm.}$$

⊛ Density of nuclei of all types of element is same and its order is 10^{17} kg/m³ or 10^{14} gm/cm³

Mass Defect

$\Delta m =$ expected mass − observed mass

$$\Delta m = Z m_p + (A-Z) m_n - M_{nucleus}$$

Also, Energy → $\boxed{Q = (\Delta m) c^2}$

Also, $Q = (\Delta M)\, 931.5$ MeV

ΔM → AMU

Binding Energy → $\Delta m c^2$

(*) $\underline{A + B} \longrightarrow \underline{C + D} + \underbrace{Q}_{\text{energy}}$

$Q > 0$ → energy is released.
$Q < 0$ → energy is absorbed.

$$E = (m_{reactant} - m_{product})\, 931.5 \text{ MeV.}$$

Now,
$$Q = (B.E)_{product} - (B.E)_{Reactant}$$

Binding Energy per nucleon

$$= \left(\frac{\Delta E_b}{A}\right)$$

Greater the binding energy per nucleon,
↑ the stability of nucleus

NOTE:- B.E of a nucleus is the energy required to split it into its nucleons (free).