e/m of an electron (Thomson Method):-

(a) e/m of a particle is called the specific charge of the particle.

$e/m = v/rB$

Here, r is the radius of curvature, B is the strength of magnetic field, v is the velocity, e is the charge on cathode ray particle and m is the mass.

(b) $v = E/B$

Electric field:- $E = V/d$

Photo electric effect:- Photo-electric effect is the phenomenon of emission of electrons from the surfaces of certain substances, mainly metals, when light of shorter wavelength is incident upon them.

Effect of collector's potential on photoelectric current:-

(a) Presence of current for zero value potential indicates that the electrons are ejected from the surface of emitter with some energy.

(b) A gradual change in the number of electrons reaching the collector due to change in its potential indicates that the electrons are ejected with a variety of velocities.

(c) Current is reduced to zero for some negative potential of collector indicating that there is some upper limit to the energy of electrons emitted.

(d) Current depends upon the intensity of incident light.

(e) Stopping potential is independent of the intensity of light.

Effect of intensity of light:- The photoelectric current is directly proportional to the intensity of incident radiation.

Effect of frequency of light:-

(a) Stopping potential depends upon the frequency of light. Greater the frequency of light greater is the stopping potential.

(b) Saturation current is independent of frequency.

(c) Threshold frequency is the minimum frequency, that capable of producing photoelectric effect.

Laws of Photo-electricity:-

(a) Photoelectric effect is an instantaneous process.

(b) Photoelectric current is directly proportional to the intensity of incident light and is independent of its frequency.

(c) The stopping potential and hence the maximum velocity of the electrons depends upon the frequency of incident light and is independent of its frequency.

(d) The emission of electrons stops below a certain minimum frequency known as threshold frequency.

Energy contained in bundle or packet:-

$E = hf = hc/\lambda$

Here h is the Planck's constant and f is the frequency.

Work function:- It is defined as the minimum energy required to pull an electron out from the surface of metal. It is denoted by W_0.

Einstein's equation of photoelectric effect:-

(a) $\frac{1}{2} mv_{max}^2 = hf - W_0$

(b) $\frac{1}{2} mv_{max}^2 = hf - hf_0 = h(f- f_0) = h [c/\lambda - c/\lambda_0]$

(c) $eV_0 = hf - W_0$

(d) $V_0 = [(h/e)f] - [W_0/e]$

Here f_0 is threshold frequency.

Threshold frequency (f_0):- f_0 = work function/h = W/h

Maximum kinetic energy of emitted photo electrons:-

$K_{max} = \frac{1}{2} mv_{max}^2 = eV_0$

Threshold wavelength:- $\lambda_0 = c/f_0 = hc/hf_0 = hc/W$

Slope of V_0˜ v graph:- Slope= h/e

Rest mass of photon = 0, Charge = 0

Energy of photon:- $E = hf = hc/\lambda$

Momentum of photon:- $p = E/c = h/\lambda = hf/c$

Mass od photon:- $m = E/c^2 = h/c\lambda = hf/c^2$

For electron, $\lambda_e = [12.27/\sqrt{V}]$Å

For proton, $\lambda_p = [0.286/\sqrt{V}]$Å

For alpha particle, $\lambda_\alpha = [0.286/\sqrt{V}]$Å

For particle at temperature T, $\lambda = h/\sqrt{3mKT}$ $(E = 3/2\ KT)$

The wavelength of electron accelerated by potential difference of V volts is:-

$\lambda_e= [12.27/\sqrt{V}]$Å

Number of photons:-

(a) Number of photons per sec per m^2, n_p = Intensity/hf

(b) Number of photons incident per second, n_p = Power/hf

(c) Number of electrons emitted per second = (efficiency per surface)× (number of photons incident per second)

Compton wave length:-

(a) $\lambda_c = h/m_0c$

Here h is the Planck's constant, m_0 is the rest mass of electron and c is the speed of light.

(b) Change in wavelength:- $\lambda' – \lambda = \lambda_c$ (1-cos?)

de Broglie wavelength (λ):- $\lambda = h/mv = h/\sqrt{(2mE)} = h/\sqrt{(2meV)}$

In accordance to Bohr's postulate of atomic structure, the angular momentum of an electron is an integral multiple of h/2π.

So, $mvr = nh/2\pi$

Bragg's diffraction law:- $2d\sin\theta = n\lambda$

Here λ is the wavelength of electron and d is distance between the planes.

Rutherford's atomic model (α-particle scattering):-

(a) $N(\theta) \propto \text{cosec}^4(\theta/2)$

(b) Impact parameter, $b = [(Ze^2)(\cot\theta/2)]/[(4\pi\varepsilon_0)E]$

Here, $E = ½ mv^2$ = KE of theα particle.

(c) Distance of closest approach, $r_0 = 2Ze^2/(4\pi\varepsilon_0)E$

Here $E = ½ mv^2$ = KE of the α particle.

Bohr's atomic model:-

(a) The central part of the atom called nucleus, contains whole of positive charge and almost whole of the mass of atom. Electrons revolve round the nucleus in fixed circular orbits.

(b) Electrons are capable of revolving only in certain fixed orbits, called stationary orbits or permitted orbits. In such orbits they do not radiate any energy.

(c) While revolving permitted orbit an electron possesses angular momentum L (= mvr) which is an integral multiple of h/2π.

$L=mvr=n(h/2\pi)$

Here n is an integer and h is the Planck's constant.

(d) Electrons are capable of changing the orbits. On absorbing energy they move to a higher orbit while emission of energy takes place when electrons move to a lower orbit. If f is the frequency of radiant energy,

$hf= W_2-W_1$

Here W_2 is the energy of electron in lower orbit and W_1 is the energy of electron in higher orbit.

(e) All the laws of mechanics can be applied to electron revolving in a stable orbit while they are not applicable to an electron n transition.

Bohr's Theory of Atom:-

(a) Orbital velocity of electron:- $v_n= 2\pi kZe^2/nh$

For a particular orbit (n= constant), orbital velocity of electron varies directly as the atomic number of the substance.

$v_n \propto Z$

(b) For a particular element (Z= constant), orbital velocity of the electron varies inversely as the order of the orbit.

$v_n \propto 1/n$

(c) $v = nh/2\pi mr$

Relation between v_n and v_1:-$v_n = v_1/n$

Radius of electron:-

$r = n^2h^2/4\pi^2kmZe^2$

So, $r \propto n^2$

For, C.G.S system (k = 1), $r = n^2h^2/4\pi^2mZe^2$

S.I ($k = 1/4\pi\varepsilon_0$), $r = (\varepsilon_0/\pi)\ (n^2h^2/mZe^2)$

Kinetic energy of the electron:- It is the energy possessed by the electron by virtue of its motion in the orbit.

$K.E = ½\ mv^2 = ½\ k\ (Ze^2/r)$

Potential energy:- It is the energy possessed by the electron by virtue of its position near the nucleus.

$P.E = -k\ (Ze^2/r)$

Total energy:-

$W = K.E + P.E$

$W = -½\ k\ (Ze^2/r) = -k^2\ 2\pi^2Z^2me^4/n^2h^2$

For, C.G.S (k = 1), $W = -\ [2\pi^2Z^2me^4/n^2h^2]$

For, S.I. ($k = 1/4\pi\varepsilon_0$), $W = -\ (1/8\varepsilon_0^2)\ [Z^2me^4/n^2h^2]$

Since, $W \propto 1/n^2$, a higher orbit electron possesses a lesser negative energy (greater energy) than that of a lower orbit electron.

Frequency, wavelength and wave number of radiation:-

Frequency, $f = k^2[2\pi^2 Z^2 me^4/h^3]\ [1/n_1^2 - 1/n_2^2]$

Wave number of radiation,

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

Here R is the Rydberg's constant and its value is,

$R = k^2\ [2\pi^2 Z^2 me^4/ch^3]$

Bohr's theory of hydrogen atom (Z=1):-

(a) Radius of orbit:-

$r = n^2h^4/4\pi^2me^2$ (C.G.S)

$r = (\varepsilon_0/\pi)\ (n^2h^2/me^2)$ (S.I)

(b) Energy of electron:-

$W = 2\pi^2me^4/n^2h^2$ (C.G.S)

$W = (1/8\varepsilon_0)[me^4/n^2h^2]$

(c) Frequency, wavelength and wave number of radiation:-

C.G.S:- k =1 and Z=1

Frequency= $f = 2\pi^2me^4/h^3\ [1/n_1^2 - 1/n_2^2]$

Wave number = $1/\lambda = 2\pi^2me^4/ch^3\ [1/n_1^2 - 1/n_2^2]$

S.I:- $k = 1/4\pi\varepsilon_0$ and Z=1

Frequency= $f = (1/8\varepsilon_0)\ (me^4/h^3)[1/n_1^2 - 1/n_2^2]$

Wave number = $1/\lambda = (1/8\varepsilon_0^2)\ (me^4/ch^3)[1/n_1^2 - 1/n_2^2]$

Rydberg's constant:-

$R = k^2 = 2\pi^2 z^2\ me^4/ch^3$

For hydrogen atom, Z = 1, $R = R_H = k^2\ (2\pi^2\ me^4/ch^3)$.

For C.G.S system (k=1), $R_H = 2\pi^2\ me^4/ch^3$

For S.I system ($k=1/4\pi\varepsilon_0$), $R_H = (1/8\varepsilon_0^2)\ (me^4/ch^3)$

Wave number, $1/\lambda = R_H\ [1/n_1^2 - 1/n_2^2]$

Hydrogen Spectrum:-

(a) For Lyman series:- $1/\lambda = R\ [1 - 1/n^2]$, n = 2,3,4…..∞

(b) For Balmer series:- $1/\lambda = R\ [1/2^2 - 1/n^2]$, n =3,4,5…..∞

(c) For Paschen series:-$1/\lambda = R\ [1/3^2 - 1/n^2]$, n =4,5,6…..∞

(d) For Brackett series:-$1/\lambda = R\ [1/4^2 - 1/n^2]$, n =5,6,7…..∞

(e) P-fund series:-$1/\lambda = R\ [1/5^2 - 1/n^2]$, n =6,7,8…..∞

Series limits ($^{\lambda}$min):-

(a) Lyman:- λmin = 912 Å

(b) Balmer:-λ_{min} = 3645 Å

(c) Paschen:- λ_{min} = 8201 Å

Energy levels of hydrogen atom:-

$W = -k^2 2\pi^2 me^4/n^2h^2$

For, n=1, W_1 = -13.6 eV

For the first excited state, *n*=2, $W_2 = W_1/4$ = (-13.6/4) *eV* = -3.4 *eV*

For the second excited state, n=3, $W_3 = W_1/9$ = (-13.6/9) eV = -1.51 eV

Similarly, for other excited states, W_4 = -0.85 eV and W_5 = -0.54 eV

Number of emission lines from excited state:-n = n(n-1)/2

Ionization energy:-

$- E_1 = +(13.6Z^2)eV$

(a) For H-atom, I.E = 13.6 eV

(b) For He^+ ion, I.E = 54.4 eV

(c) For Li^{++} ion, I.E = 122.4 eV

Ionization potential:-

(a) For H-atom, I.P = 13.6 eV

(b) For He^+ ion, I.P = 54.42 eV