Dual Nature Of Radiation And Matter

Photoelectric effect

- Phenomenon of emission of electrons from the surface of metals when radiations of suitable frequency fall on them.

Work function of a metal

- It is the minimum energy required to liberate an electron from the surface of a metal without imparting any kinetic energy.

Factors affecting photoelectric effect:

- The number of photoelectrons ejected per second is directly proportional to the intensity of the incident light.
- For an incident radiation of frequency less than the threshold frequency, no emission of photoelectron is possible, even if the intensity is high.
- The maximum kinetic energy of the emitted photoelectron depends only upon the frequency $or wavelength$ of the incident light, and is independent of the intensity of the incident light.

Einstein's Photoelectric Theory

Light radiation consists of small packets of energy called quanta.
One quantum of light radiation is called a photon, which travels at the speed of light.
Energy of a photon, $E = h\nu$.

The energy of an an electron falling on a metal energy is used for:

liberating the electron from the metal surface $= work function$

imparting maximum kinetic energy k_{max} to the emitted photoelectrons

$$h\nu = \Phi_0 + \frac{1}{2}mv^2{}_{max}$$

Einstein's Photoelectric Equation:

$$K_{max} = \frac{1}{2}mv^2 = h\nu - \Phi_0$$

Here,

K_{max}= Maximum kinetic energy of the emitted electrons

v= Maximum velocity of the electrons

ϕ_0= Work function of the metal

Photoelectric Cell

- It is a device that converts light energy into electrical energy.
- It works on the principle of photoelectric effect.

Applications of photoelectric cell :

Exposure metre

Burglar alarm

Sound reproduction in motion pictures

Properties of Photons

All photons of light of a particular frequency ν, or wavelength λ, have the same energy *E* (=*h*ν =*hc*/λ) and momentum *p* (= *h*ν/*c*), independent of the intensity of radiation.

By increasing the intensity of light of given wavelength, there is only an increase in the number of photons per second crossing a given area, with each photon having the same energy.

Photons are electrically neutral and are not deflected by electric and magnetic fields.

In a photon particle collision, the total energy and total momentum are conserved. However, the number of photons may not be conserved in a collision

Dual nature of matter

- Matter possesses dual nature: particle-like as well as wave-like nature.
- **de Broglie's Hypothesis**
  - A moving particle sometimes acts as a wave and sometimes as a particle; or a wave is associated with a moving material particle which controls the particle in every respect.
  - The wave associated with the moving particle of is called matter wave.
  - de Broglie wavelength is given by $\lambda = \frac{h}{mv}$, where *m* = mass of particle; *v* = velocity of the particle and h = planck's constant.
- According to de Broglie, every moving particle is associated with a wave of wavelength given by $\lambda = \frac{h}{p} = \frac{h}{mv}$.
- According to Bohr's 2nd postulate, angular momentum of an electron is given by $\lambda = n\frac{h}{2\pi}$.
- According to de Broglie, wavelength of an electron in terms of voltage is given by $\lambda = \frac{12.27}{\sqrt{V}}$ A°.

Davisson and Germer Experiment

- It confirmed wave nature of the matter that was given in De-Broglie's hypothesis.
- In the experiment
  - The electrons from an electron gun were made to strike the Nickel crystal
  - Scattering of electrons was observed.
  - The intensity of the electrons in the given direction was measured.
  - Graph was plotted between intensity and the angle of reflection.
  - Maximum intensity was observed at $\theta = 50^{o}$ the energy of the electron beam being 54 eV with a voltage of 54 V.