Chapter Eleven

DUAL NATURE OF RADIATION AND MATTER

(Prepared by AYYAPPAN C, HSST, GMRHSS KASARAGOD)

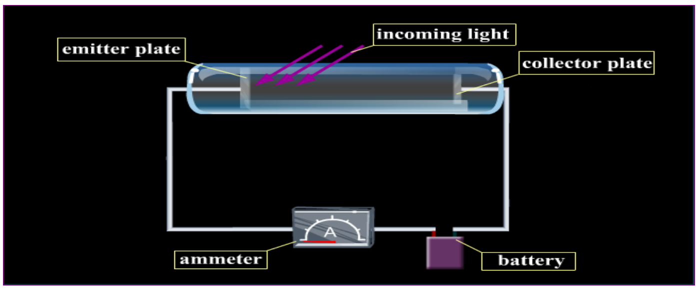
PHOTOELECTRIC EFFECT

- **The phenomenon of ejection of electrons when light of suitable frequency falls on it is called photoelectric effect.**
- Photoelectric emission was discovered in by **Heinrich Hertz.**
- In photoelectric effect the light energy is converted to electrical energy.
- The photo (light)-generated electrons are called ***photoelectrons*** and the current is called ***photo current.***
- Substances that respond to light are called ***photo sensitive substances.***
- Metals like **zinc, cadmium, magnesium** etc respond only to **ultra violet light**.
- Alkali metals such **as lithium, sodium, potassium, cesium and rubidium** are sensitive **to visible light**.

Hallwachs' and Lenard's observations

- Wilhelm Hallwachs and Philipp Lenard studied photo electric effect in detail using an evacuated glass tube with two zinc plates as electrodes.

Experimental set up



Observations

- When ultraviolet radiations were allowed to fall on the emitter plate current flows in the circuit.
- When collector plate is illuminated no current flows.
- When the frequency of incident radiation is less than a certain minimum value no photo electrons emission is possible. This minimum frequency is called **threshold frequency.**
- Threshold frequency depends on the nature of the metal.

Laws of Photoelectric emission

- **The photoelectric current is directly proportional to the intensity of incident light and independent of the frequency.**
- **Kinetic energy of emitted photo electrons depends on the frequency and does not depend on intensity of radiation.**
- **For each metal there is a threshold frequency, below which no photoelectron emission is possible.**
- **The photoelectric emission is an instantaneous process.**

EINSTEIN'S EXPLANATION OF PHOTO ELECTRIC EFFECT

- Einstein explained photoelectric effect based on quantum theory.
- According to quantum theory, light contain photons having energy hν.
- When a photon of energy **hν** is incident on a metal surface, electrons are emitted.
- A part of the photon energy is used as the work function and the remaining part of the photon energy appears as the kinetic energy of photoelectrons.

Einstein's photoelectric equation

- Photon Energy = Work function + maximum K.E. of photoelectron.
- That is

$$h\nu = \phi_0 + K_{\max}$$

- Thus

$$\boxed{K_{\max} = h\nu - \phi_0}$$

- But the work function is given by $\phi_0 = h\nu_0$, where ν_0 is the **threshold frequency**.
- Therefore

$$K_{\max} = h(\nu - \nu_0)$$

- This equation is the Einstein's photo electric equation.

Frequency - stopping potential graph (for different metals)

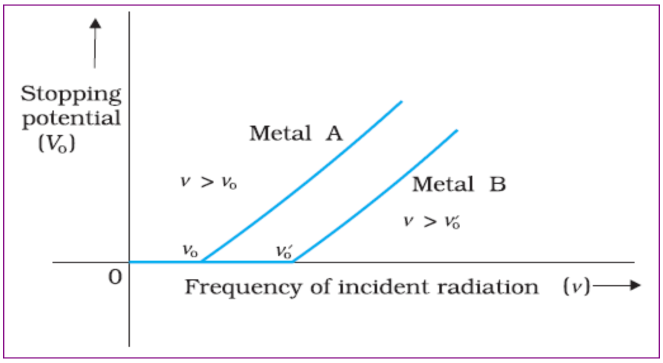
- We have, the photo electric equation,

$$\boxed{K_{max} = h\nu - \phi_0}$$

- Also in terms of stopping potential

$$\boxed{K_{max} = e\,V_0}$$

- Thus $eV_0 = h\nu - \phi_0$
- That is $$V_0 = \frac{h}{e}\nu - \frac{\phi_0}{e}$$
- It predicts that the V_0 *versus* ν *curve is a* straight line with slope = (*h/e), independent of the nature of the material.*



- Thus **Planck's constant =slope** X **charge of electron.**
- The y-intercept is $-\frac{\phi_0}{e}$, therefore the **work function = - (y intercept)** X **charge of electron.**

Photoelectric cell

- Photoelectric cell is a device used to convert light energy into electric energy using the principle of photoelectric effect.

PARTICLE NATURE OF LIGHT:

THE PHOTON

- **In interaction of radiation with matter, radiation behaves as if it is made up of particles called photons.**

Properties of Photons

- Each photon has energy *E (=hν) and momentum p (= h ν/c), and* speed *c, the speed of light.*
- All photons of light of a particular frequency ν*, or wavelength λ, have* the same energy *E (=hν = hc/λ) and momentum p (= hν/c = h/λ), independent of intensity of light*.
- 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**.**
- The photon energy is independent of intensity of radiation.
- Photons are electrically neutral and are not deflected by electric and magnetic fields.
- In a photon-particle collision (such as photon-electron collision), the total energy and total momentum are conserved.
- However, the number of photons may not be conserved in a collision. The photon may be absorbed or a new photon may be created.

Dual nature of radiation

- Radiation has wave nature as well as particle nature. This is called the dual nature of radiation.

*****