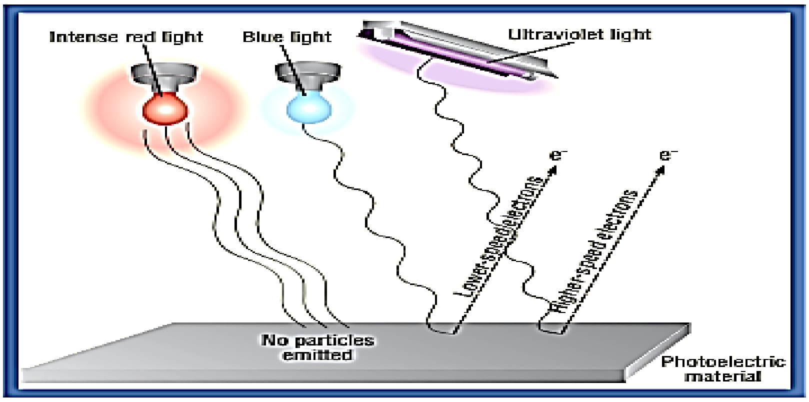
❖ Photoelectric Effect

❖ The ***photoelectric effect*** is the emission of electrons from the metal surface when light incidents on it's surface.



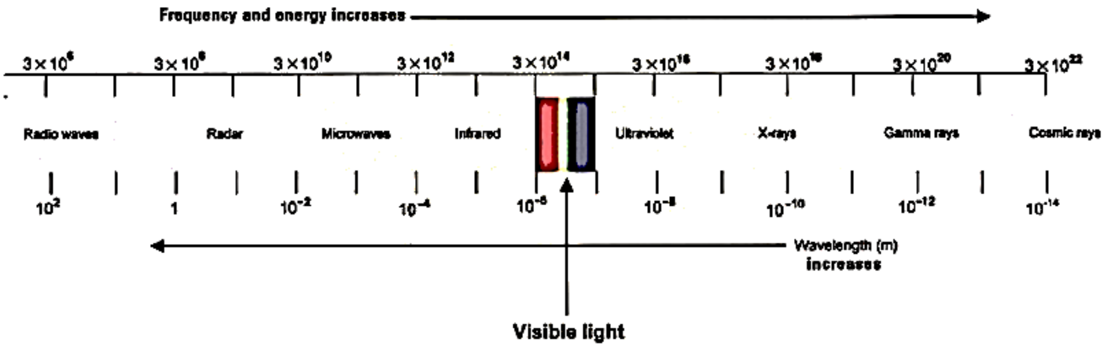
❖ This effect is used in many devices, including TV, cameras, camcorders, and night vision viewers.

❖ In 1887, **Heinrich Hertz** discovered that when electromagnetic radiation (***photons***) incidents on a clean, metal surface, electrons are emitted from the surface.

❖ Some of the incident photons enter the surface of metal, collide with atoms of the metal, and are totally absorbed.

❖ Some of the incident photons give their energy to an electron. If the absorbed energy was great enough, then electrons break free from the atom.

❖ In the classical theory, the photoelectric effect should occur for any frequency of the light if the light is intense enough to give the energy required for the electrons to escape from the metal surface.



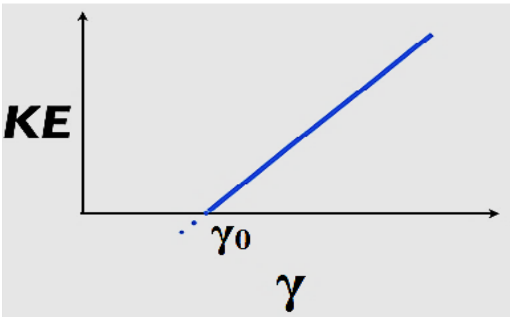
- ***Phillip von Leonard***, an assistant of ***Hertz***, showed that for each surface material, there is a **Critical Frequency** or **Threshold frequency** (γ_0) (Is the frequency required for releasing the electron from the surface of metal without providing it with any kinetic energy).
- **Threshold frequency:** Is defined as the minimum **frequency** of light which causes electrons to be emitted from a metal surface.
- **The practical results of Hertz are as follows**:-

  1- The number of electrons emitted from metal depends on the ***intensity*** and ***frequency*** of incident light.

  2- The maximum kinetic energy (**KE_{max}**) of the emitted electrons ***depends*** on the ***frequency*** of the incident light and is ***independent*** of the ***intensity***.

- **Max Planck** postulated that a beam of light consists of a collection of discrete packets of energy called ***photons***. Each photon contains an amount of energy *E* given by following eq. (4).

$$E_{photon} = h*\upsilon \quad \text{..............................(4)}$$



- The slope of the graph is **h**, **Planck's** constant. The value for the critical frequency is simply the **x intercept**. The work function would be the **y intercept**, but KE cannot be less than zero.
- **h**= Planck's constant = **$6.626*10^{-34}$ J.sec** = **$6.626*10^{-27}$ erq.sec**.
- **1 Joule = $1*1^{07}$ erq**

- **J = Kg * m^2 * Sec^{-2} = g * cm^2 * sec^{-2}**

$$E = mc^2$$

$$E = Kg.\ (m.s^{-1})^2$$

$$E = Kg.\ m^2.s^{-2}$$

$$\text{So } 1\ J = Kg.\ m^2.s^{-2}$$

- **(Work Function)**, **W_0:** Is the energy required for releasing (removing) the electron from the surface of metal without providing it with any kinetic energy, eq. (5).
- **$W_0 = h * \upsilon_0$ ………………………...(4)**
- The work required depends on how strongly the electron is held. For the ***least strongly*** held electrons, the necessary work has a minimum value **W_0** and is called the ***work function*** of the metal. If a photon has energy in ***excess*** of the work needed to remove an electron, the excess energy appears as ***kinetic energy*** of the ejected electron. Thus, the least strongly held electrons are ejected with the maximum kinetic energy KEmax.
- Einstein applied the principle of conservation of energy and proposed the following relation [eqs. (5-10)] to describe the photoelectric effect:
- **$KE_{max} = h*\gamma - W_0$ …………..(5)**
- **$E_{photon} = h*\upsilon = W_0 + \frac{1}{2} m*v^2$ ……….….(6)**
- **$KE_{max} = (h*C) / \lambda - W_0$ ………..…(7)**
- **$\frac{1}{2} m*v^2 = (h*C) / \lambda - h * \upsilon_0$ …………...(8)**
- **$h * \upsilon_0 = (h*C) / \lambda - \frac{1}{2} m*v^2$ ……………(9)**
- **$\upsilon_0 = C / \lambda - (m*v^2) / 2h$ ....………....(10)**
- **m = electron mass, v = velocity of electron**
- Since the work function, which is the energy required to release an electron from the metal surface is a constant for any given material, the maximum kinetic energy depends directly on the frequency of the incoming (incident) light. It is also clear that there is a minimum light

frequency for a given metal, for which the photon energy is equal to the work function. Light below that frequency, no matter how intense, will not cause photoelectric effect.

- **Note:-** The energy units are (Joule or erq), (Joule.mol^{-1} or erq.mol^{-1}), (**e.v** electron volt, where **1 e.v = 1.6022*10^{-19} J**).

Ex. An FM radio station broadcasts at a frequency of (91.5 *10^{6} s^{-1}). Calculate the energy in following units. **1-** Joule. **2-** erq. **3-** J.mol^{-1} **4-**erq.mol^{-1} **5-**e.v

Ans.

1- E = h * γ

(6.626*10^{-34} J. S) * (91.5 *10^{6} s^{-1}) = **(6.06*10^{-26} J)**

2- To obtain the energy in (Joule.mol^{-1}) unit, we must multiply the energy in Joule unit with Avogadro's Number (N_A= 6.023 * 10^{23} mol^{-1})

(6.06*10^{-26} J * 6.023 * 10^{23} mol^{-1})

= **0.0365 J.mol^{-1}**

3- E=h*γ

(6.626*10^{-27} erq.s) * (91.5 *10^{6} s^{-1})

= 6.062*10^{-19} erq

4- To obtain the energy in (erq.mol^{-1}) unit, we must multiply the energy in erq unit with Avogadro's Number (N_A= 6.023*10^{23} mol^{-1})

(6.062*10^{-19} erq) * (6.023 * 10^{23} mol^{-1})

= **365161.8 erq.mol^{-1}**

5- 6.06*10^{-26} Joule *(**1 e.v/1.6022*10^{-19} Joule**) = **3.784*1^{-27} e.v**

❖ **H.W**:- Calculate the maximum KE_{max} (J) and velocity ($m.sec^{-1}$) of an electron ejected from zinc by a 275nm photon. (Wo=4.31 e.v, $c=3*10^{8}$ $m.Sec^{-1}$). **Ans. ($3.2*10^{-20}$J, $2.65*10^{5}$ m/s).**

❖ **H.W:-** Calculate the maximum kinetic energy (e.v) of an electron ejected from silver by a $3.13*10^{15}$Hz photon. (W_0=4.73 ev). Ans. (8.22 e.v)