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PHYSICS

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CLASS 11&12th

CLASS 12th

Modern Physics-I

01. Dual Nature of Radiation

The phenomena such as interference, diffraction and polarization were success-fully explained on the basis of were nature of light. On the other hand, photoelectric effect, Compton effect, etc can be explained on the basis of quantum nature of radiation.

02. Electron Emission

A metal has free electrons, but these electrons cannot come out of the metal surface. It is because, as an electron makes an attempt to come out of the metal surface, the metal surface acquires positive charge and the electron is pulled back into the metal. Thus, free electrons are held inside the metal surface by the positive ions, it contains. In order that an electron may come out of the metal surface, it must possess sufficient energy to overcome the attractive pull of the positive ions.
The minimum amount of energy required to eject an electron out of a metal surface is called **work function** of the metal. It is denoted by ω.
The work function of a metal depends on the nature of the metal. The following table gives the work functions of a few metals:

Work functions of some metals									
Metal	**Cs**	**K**	**Na**	**Ca**	**Mo**	**Al**	**Cu**	**Ni**	**Pt**
Work function (eV)	2.14	2.30	2.75	3.20	4.17	4.28	4.65	5.15	5.65

By supplying energy atleast equal to work function, the electron emission can be caused from a metal surface by the following processes:
(i) **Thermionic emission.** It can be caused by supplying the minimum required energy by heating the metal surface to a suitable temperature.
(ii) **Field emission.** It can be caused by applying an electric field to the metal surface. If the electric field is sufficiently strong $\left(\approx 10^8\ \mathrm{V\,m^{-1}}\right)$, the electrons get pulled out of the metal surface.
(iii) **Photoelectric emission.** It can be caused by supplying the minimum required energy by illuminating the metal surface with light of suitable frequency.
(iv) **Secondary emission.** The process of emission of free electrons when highly energetic election beam is incident on a metal surface is called secondary emission. The electrons so emitted are called secondary electrons.

03. Photoelectric Effect

The phenomenon of emission of electrons from (preferably) metal surface exposed to light energy of suitable frequency is known as photoelectric effect.
The emitted electrons are called photo electrons and the current so produced is called photoelectric current.
Alkali metals (lithium, sodium, potassium, caesium etc.) show photoelectric effect with visible light, whereas the metals like zinc, cadmium magnesium etc. are sensitive only to ultraviolet light.

Hertz's Observations

The phenomenon of photoelectric emission was discovered in 1887 by Heinrich Hertz (1857−1894) while studying experimentally the production of electromagnetic waves by means of spark discharge. He found that when the emitter plate was illuminated by ultraviolet light, high-voltage sparks across the detector loop were enhanced. This observation led him to conclude that light facilitated the emission of some electrons.

From this it was concluded that when suitable radiation falls on a metal surface, some electrons near the surface absorb enough energy from the incident radiation to overcome the attraction of the positive ions in the material of the surface.

Hallwachs' and Lenard's Observations

Wilhelm Hallwachs and Philipp Lenard studied in detail the phenomenon of photoelectric effect during 1886−1902.

Lenard (1862−1947) observed flow of current when ultraviolet radiations is exposed on the emitter plate of an evacuated glass tube enclosing two electrodes (metal plate). The current flow stops as soon as the ultraviolet radiations were stopped. These observation indicated that electrons are ejected from emitter plate C, when ultraviolet radiations fall on it which are attracted towards the positive, collector plate A by the electric field.

Thus current in the external circuit is due to light falling on the surface of the emitter. Hallwachs and Lenard studied variation of photocurrent with collector plate potential and with frequency and intensity of incident light.

Hallwachs, in 1888 for further study, connected a negatively charged zinc plate to an electroscope. He found that when zinc plate was illuminated by ultraviolet light it has lost its charge. When uncharged zinc plate was illuminated by ultraviolet light, it became positively charged. Further when positively charge zinc plate was illuminated by ultraviolet light it was found to be further enhanced. He concluded from these observations that under the action of ultraviolet light negatively charged particles were emitted from the zinc plate.

It became evident after the discovery of the electron in 1897 that the incident light causes electrons to be emitted from the emitter plate. The emitted electrons due to tis negative charge are pushed towards the collector plate by the electric field. Hallwachs and Lenard also observed that when the frequency of the incident light was smaller than a certain minimum value, no electrons were emitted at all from the emitter plate. This minimum frequency is called the threshold frequency and it depends on the nature of the material of the emitter plate.

It was found that some alkali metals such as lithium, sodium, potassium, caesium and rubidium were sensitive even to visible light whereas certain metals like zinc, cadmium, magnesium etc. responded only to ultraviolet light, having short wavelength for electron emission from the surface. Electrons are emitted, when photosensitive substances are illuminated by light. These electrons were termed as photoelectrons after the discovery of electrons. This phenomenon is known as photoelectric effect. The electric current constituted by photo-electrons is known as photoelectric current.

04. Experimental Study of Photoelectric Effect

The experimental set-up to study photoelectric effect is shown in figure. It consists of an evacuated glass or quartz tube having two electrodes. The electrode 'C' is a photosensitive plate, which emits photoelectrons when exposed to ultraviolet radiation. The electrode 'A' is a charge-collecting plate. The tube has a side window, which will allow the light of a particular wavelength to pass through it and falls on the photosensitive plate 'C'.

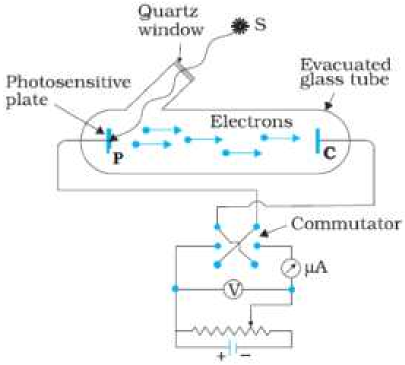

Fig.: Experimental arrangement for study of photoelectric effect.

The window is made of quartz covered with a filter. The electrons collected by the plate A (collector), are emitted by the plate C. Battery creates the electrical field between collector and emitter. The potential difference between the plates C and A is maintained by the battery, which can be varied. From a commutator the polarity of the plates C and A can be reversed. Thus with respect to emitter C, the plate A can be maintained at a desired positive or negative potential. The electrons are attracted when the collector plate A is positive with respect to the emitter plate C. Electron emission causes flow of electric current in the circuit. Voltameter (V) measures the potential difference between the emitter and collector plates. Microammeter (μA) measures the resulting photocurrent flowing in the circuit. The current flowing in the circuit can be increased or decreased by varying the potential between collector plate A and emitter plate C. We can also vary the intensity and frequency of the incident light.

To study the variation of photocurrent with (a) intensity of radiation (b) frequency of incident radiation (c) the potential difference between the plates A and C, and (d) the nature of the material of plate C, the experimental arrangement of above figure is used.

To get different frequency of light falling on the emitter C, suitable-coloured filter or coloured glass is used. The change is distance of light source from the emitter varies the intensity of light.

Effect of Intensity of Light on Photocurrent

To attract ejected electron from C towards collector A, the collector A is maintained at a positive potential with respect or emitter C. The intensity of light is varied, keeping the frequency of the incident radiation and the accelerating potential fixed and the resulting photoelectric current is measured each time. It is observed that the photocurrent increases linearly with intensity of incident light as shown in the figure.