



2024 - 25

Dual Nature of Radiation and Matter

Recall what did you study in previous class

Planck's Quantum Theory

- According to Planck's quantum theory, light is considered to be made up of small packets (or particles) of energy known as quanta of energy or radiation.

$$\text{Energy, } E = hv = \frac{hc}{\lambda} = \frac{12400}{\lambda(\text{\AA})} \text{ eV}$$

Photons

- Momentum of one photon is $\frac{h}{\lambda}$
- When radiation interacts with matter, the radiation behaves as if it is made of particles like photons
- Einstein proposed that electromagnetic radiation (or simply light) is quantized and exists in elementary amounts (quanta) that we now call photons.
- Photons are not deflected by electric and magnetic fields which shows that they are neutral and do not carry any charge.
- The energy of photon depends upon the frequency of radiation but is independent of the intensity of radiation.

Photoelectric Effect

- When light of suitable frequency illuminates a metal surface, electrons are emitted. This process of ejection of electrons using light is known as photoelectric emission. Photoelectrons ejected from metal have kinetic energies ranging from 0 to K_{max} .
- A certain minimum amount of energy is required for an electron to be pulled out from the surface of a metal. This minimum energy is called the work function (ϕ) of that metal. Work function is minimum for cesium (1.9 eV).
- Einstein equation for photoelectric effect is, $hv = \phi + KE_{\text{max}} \Rightarrow \frac{hc}{\lambda} = \frac{hc}{\lambda_0} + eV_s$
- The minimum frequency of the incident light below which photoelectrons are not ejected from the metal surface is known as threshold frequency (ν_0).
- Work function, $\phi = h\nu_0 = \frac{hc}{\lambda_0}$
 $\lambda_0 =$ Threshold wavelength
- The minimum negative potential given to the metal plate with respect to the collector at which the photoelectric current becomes zero is known as stopping potential or cut-off potential. Here $\text{max } KE_{\text{max}} = eV_s$, V_s stopping potential
- The number of photoelectrons emitted per second is directly proportional to the intensity of the incident radiation



- The maximum kinetic energy of the ejected electrons is independent of the intensity of incident radiation but depends upon the frequency of the incident radiation.

De-Broglie Hypothesis

- It says that a wave is associated with a moving material particle. The wavelength associated with a moving particle is given by $h = mv\lambda$, where m is the mass of the particle moving with v velocity and h is Planck's constant. This wave is called de-Broglie wave.
- Matter waves cannot be electromagnetic in nature because electromagnetic waves are produced by motion of charged particles.

Heisenberg's Uncertainty Principle

- According to Heisenberg's Uncertainty Principle, it is not possible to measure exactly both the position and momentum of a microscopic particle (say electron) at the same time. That is,

$$\Delta x \Delta p \geq \frac{\hbar}{2}, \text{ where } \hbar = \frac{h}{2\pi}$$

Key Tips

- Einstein's photoelectric equation, $\frac{1}{2}mv_{\max}^2 = hv - hv_0$
- Work function and threshold frequency or threshold wavelength related as, $\phi_0 = hv_0 = \frac{hc}{\lambda_0}$
- Energy of photon, $E = hv = \frac{hc}{\lambda}$
- Momentum of photon, $p = \frac{E}{c} = \frac{h}{\lambda}$
- de-Broglie wavelength of a material particle, $\lambda = \frac{h}{mv}$
- de-Broglie wavelength in terms of energy of a particle (E), $\lambda = \frac{h}{\sqrt{2mE}}$
- de-Broglie wavelength of an electron accelerated through a potential V volt, $\lambda = \sqrt{\frac{150}{V}} \text{ \AA} = \frac{12.27}{\sqrt{V}} \text{ \AA}$
- de-Broglie wavelength of a particle in terms of temperature (T), $\lambda = \frac{h}{\sqrt{3mkT}}$



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Library- <https://smart.link/sdfez8ejd80if>