PLANCK'S THEORY OR THEORY OF QUANTIZATION

Particle Nature of Electromagnetic Radiation Planck's Quantum Theory [Particle Nature of Light]:

He proposed that a body emits energy in the form of discontinuous packets or bundles. Each bundle is referred to as a quantum, and in the context of light, it is called a photon. The energy of each quantum is directly proportional to the frequency of radiation.

$$E \propto \nu$$

$$E = h\nu \qquad h = 6.62 \times 10^{-34}\ \text{Js.}$$

$$\downarrow$$

Plank's constant

Total energy absorbed or emitted by a body will be whole no. integral multiple of energy of quantum

$$E_{abs} \text{ or } E_{emitted} = nh\nu$$

Ex. **Calculate the no. of photons emitted by 60-watt bulb in 10 hrs. When light of wavelength 6000 Å is emitted by it.**

Sol. $E = \frac{nhc}{\lambda} = 6.5 \times 10^{24}$

Energies in Electron Volts

Room temperature thermal energy of a molecule: 0.04 eV
Visible light photons: 1.5-3.5 eV
Energy required for the dissociation of an NaCl molecule into Na^+ and Cl^- ions: 4.2 eV
Ionization energy of atomic hydrogen: 13.6 eV
Approximate energy of an electron striking a color television screen (CRT display): 20,000 eV High-energy diagnostic medical x-ray photons: 200,000 eV (0.2 MeV)

Typical energies from nuclear decay:

(1) Gamma: 0-3 MeV
(2) Beta: 0-3 MeV
(3) Alpha: 2-10 MeV

Cosmic ray energies: 1 MeV – 1000 TeV

$1\ \text{MeV} = 10^6\ \text{eV}, 1\ \text{GeV} = 10^9\ \text{eV}, 1\ \text{TeV} = 10^{12}\ \text{eV}$

Explanation of black body radiations using Planck's quantum theory

As a solid substance, like a piece of iron, is heated, it emits radiation. As the heating process continues, atoms absorb more energy, leading to heightened energy emission. Consequently, the energy and frequency of the electromagnetic waves increase, causing the material to shift from red to yellow and eventually to white. This supports the conclusion that light demonstrates particle nature, and the energy of electromagnetic radiation is contingent on its frequency.

Explanation of Photo electric Effect using Planck's Quantum Theory

When a metal sheet is subjected to electromagnetic radiation with a suitable frequency, specific electrons are emitted from the metal surface, known as photoelectrons, and this occurrence is identified as the photoelectric effect. In situations where electromagnetic radiation of low frequency is utilized, there is no emission of electrons despite a continuous rise in intensity. This observation

contradicted Maxwell's theory, which proposed that the energy of electromagnetic radiation is proportional to intensity ($E \propto I$). However, it is reconciled through Planck's quantum theory.

i.e. $E \propto \nu$.

Dual Nature of Light

Considering that the wave nature of light explains phenomena such as diffraction and interference, and the particle nature clarifies black body radiation and the photoelectric effect, it is inferred that light demonstrates dual characteristics, encompassing both particle and wave nature.