30 - Quantum Physics.

Q-1) What is a photon?

> A photon is a packet of energy or a quantum of electromagnetic energy.

$E = hf$ — frequency of EM radiation.

energy of a photon — Planck's constant ($6.63 \times 10^{-34}\ m^2 kgs^{-1}$)

OR $E = \frac{hc}{\lambda}$

Q-2) What is an electron volt?

> 1eV is the energy transferred when an electron travels through a potential difference of 1V.

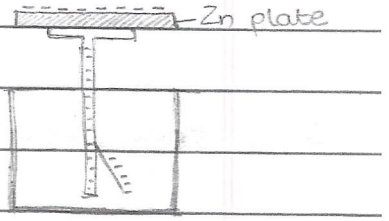
$1eV = 1.6 \times 10^{-19} J$

$\therefore 1\ MeV = 1.6 \times 10^{-13} J$

Q-3) What is the photoelectric effect?

> Photoelectric effect is the emission of electrons from the surface of a metal when light of minimum frequency falls on the metal.

When UV light is incident, electrons are emitted from the zinc plate, and the gold leaf falls since there is no repulsion.



Characteristics of photoelectric effect.

① Photoemission takes place instantaneously from the surface of a metal due to one-to-one interaction between the photon and electron.

② Photoemission takes place only if the frequency of the radiation is above the threshold frequency.
Different metals have different threshold frequencies.

③ Photoemission does not depend on intensity. However, for a particular frequency, the rate of emission is proportional to the intensity.

④ Maximum k.e of the electrons depends on the frequency of the radiation.

⑤ Energy is conserved during the interaction.

Q-4) What is the threshold frequency?

> It's the minimum frequency of light required to emit electrons from the surface of a metal. (f_0)

Q-5) What is work function?

> Work function is the minimum energy of photons required for the emission of electrons from the surface of a metal.

$W_0 = h f_0$ — threshold frequency

work function — W_0 ; Planck's constant — h

Q-6) Photoelectric equation.

photon energy = work function + max k.e of electron.

$$hf = W_0 + K.E_{max}$$

$$hf = hf_0 + \frac{1}{2} m v_{max}^2$$

* see pg 474 for wave * particulate nature of EM radiation.

Q-7) Wave and particle nature. *

> Photoelectric effect provides evidence for the particulate nature of EM radiation.

threshold frequency and instantaneous emission.

wave nature suggest emission would still occur after a long time. since e^- is continuously emitted and it collects energy continuously.

Emission occurs even at low intensity.

wave model suggests that low intensity means less energy ∴ no emission.

Increasing frequency increases K.E max of electrons.

in wave model, intensity would increase K.E max.

→ Diffraction & interference provide evidence for wave nature.

Q-8) De Broglie waves.

> Electrons also have wave nature.

$$\lambda = \frac{h}{mv} = \frac{h}{p} = \frac{h}{\sqrt{2meV}} = \frac{h}{\sqrt{2mE}}$$

h: planck's constant; λ: De Broglie wavelength; p: momentum; V: p.d.; E: k.e

equating

- $E = mc^2$ and
- $E = \frac{hc}{\lambda}$

Derivation

$\frac{1}{2}mv^2 = eV$ $\quad$ $\frac{1}{2}mv^2 = E$

$m^2v^2 = 2meV$ $\quad$ $m^2v^2 = 2mE$

$mv = \sqrt{2meV}$ $\quad$ $mv = \sqrt{2mE}$

→ De Broglie wave is the wavelength of the wave associated with a particle that is moving.

Q-9) Line spectra.

> A continuous spectrum has all colours.

* Emission spectra:

An electron loses energy when it makes a transition from a higher to a lower energy level. A photon of EM radiation is emitted because of this energy loss. This result in an emission spectrum.

* Absorption spectra:

An electron absorbs a photon of the correct energy to make a transition to a higher energy level. This results in an absorption spectrum.

Q-10) Electron energy levels.

> Line spectrum means discrete wavelengths. This shows that the photons have particular values of energy.

Energy of a photon is determined by the energy change of an electron. * ∴ the electrons must have discrete energy levels.

* Since there are discrete energy changes,

The energy levels have negative values because external energy has to be supplied to remove the electron from the atom.

An electron with zero energy is free from the atom.

$$hf = E_1 - E_2$$

E_1 → higher energy level (top)

E_2 → lower energy level (bottom).

Q-11) Band theory of solids.

> When atoms come close together, to form a solid, the presence of neighbouring atoms influences the e^- of other atoms.
Due to such interactions, energy levels of e^- are affected.
The individual energy levels now become a group of closely spaced energy levels called 'energy band'.

* Valence band:
The energy band formed by a group of energy levels of valence electrons.

* Conduction band:
The permitted energy band above the valence band.
It may be empty or partially filled.

* Forbidden energy gap:
The energy gap between the valence band and the conduction band.

Q-12) Change in resistance with temperature:

> At 0K, VB is filled and CB is empty.
As temperature rises, e^- gain energy to enter CB
Positive holes are formed in VB and lattice vibrations increase.
Effect due to increase in charge carriers outweighs effect due to increase in lattice vibration.
∴ Current increases and resistance decreases.