ABSORPTION AND EMISSION OF LIGHT IN METALS, INSULATORS AND SEMICONDUCTORS

The absorption and emission of electromagnetic radiation may involve e^- transition from one energy state to another.

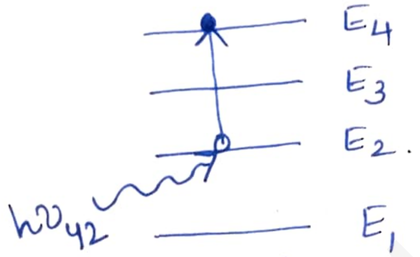

FIG 1

$\Delta E = E_4 - E_2 = h\nu_{42}$

Say an $\bar{e}$ makes a transition from 2^{nd} level to 4^{th} level.

The energy required for the transition ~~required~~ is $E_4 - E_2$.

The energy of the photon must be equal to $E_4 - E_2$.

* An $\bar{e}$ by absorbing photon of required energy makes a transition to excited state.
* Electron can't remain in excited state indefinitely. After a short time it falls/decays back to its ground state with a reemission of em radiation.

ABSORPTION & EMISSION IN METALS

Absorption

Consider the $\bar{e}$ energy band scheme as shown in fig 2a.

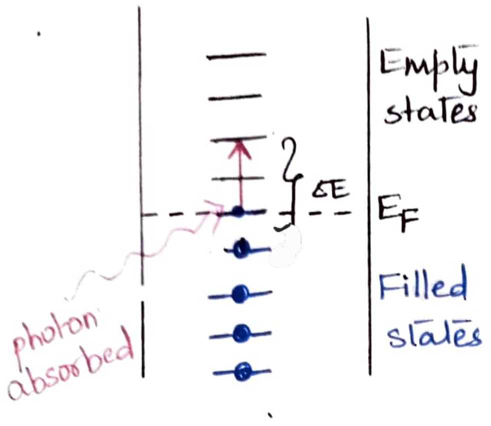

fig 2a

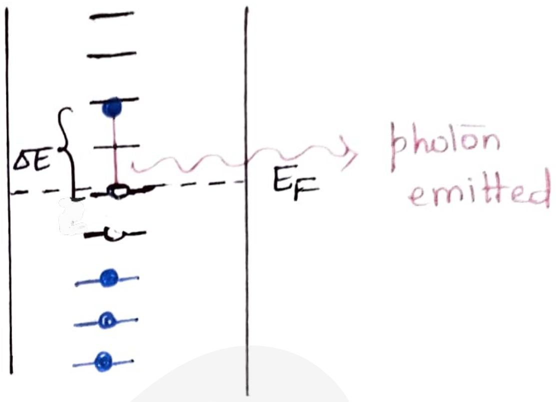

fig 2 b

In metals valence band & conduction band overlap and there exists plenty of empty states in conduction band.

* All frequencies of visible light are absorbed by metals because many empty energy levels are available to engage transition as shown in fig 2a.

* The absorption occurs upto a thickness of 0.1 μm of metal.

* Apart from visible, metals are opaque to radio, IR, ~~visil~~ and middle of UV radiation.

* Metals are transparent to x rays & γ rays

Extra NOTE

[∵ $\varepsilon_r \sim 1 - \frac{Ne^2}{\varepsilon_0 m_e \omega^2}$

as ω becomes larger n larger $\varepsilon_r \sim 1$

& refractive index $n = \sqrt{\varepsilon_r \mu_r}$, for slight magnetic material $\mu_r = 1$ ∴ $n = \sqrt{\varepsilon_r} = 1$

∴ transparent]

Emission

Consider fig 2b, absorbed photon is reemitted with the same energy.

* If a visible photon is absorbed, the absorbed photon is re-emitted from the surface in the form of visible light of the same wavelength, which appears as reflected light.

* Reflectivity of most metals is between 0.90 & 0.95.

* Color of the metal is characteristic of wavelength distribution of radiation that is reflected.

* Metals which reemit in the entire visible range appear silvery. Eg Ag & Al.

Absorption and emission in insulators

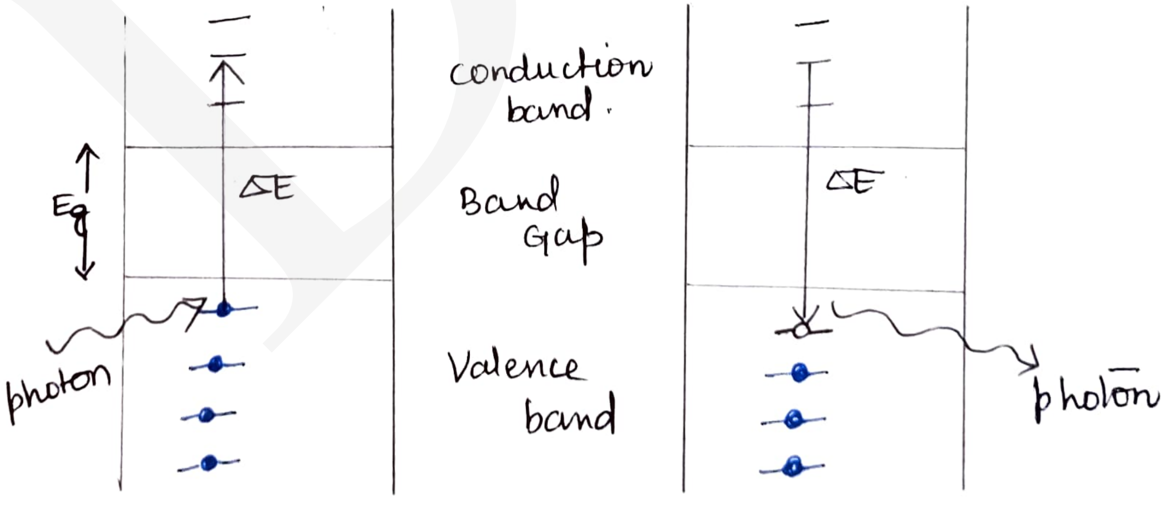

fig 3a

fig 3b

Absorption

Absorption of light photon may occur in an insulator. It results in excitation of an $\bar{e}$ from VB to CB after crossing band gap Eg as shown in fig 3a.

* This results in formation of $\bar{e}$ & hole in CB & VB respectively.

* As δE is the ~~difference~~ band gap, any excitation is possible if photon of energy

$$\boxed{h\nu > E_g}$$ impinges the $\bar{e}$ in valence band

* Most of the ~~electrons~~ have band gap greater than 3 eV. Hence, using above equation one can find minimum energy required for transition to happen.

As $h\nu = \dfrac{hc}{\lambda}$ substituting $h = 6.62 \times 10^{-34}$ Js

$C = 3 \times 10^{8}$ m/s.

and $\lambda = 400$ nm $= 400 \times 10^{-9}$ m which is minimum wavelength (or maximum freq) of visible light we get.

$E_g = 3.1$ eV

from this we conclude that most of the visible light's energy won't be sufficient to excite an $\bar{e}$ across the band gap of an isulator.

* As no absorption takes place, these materials appear transparent in purest state.

Emission

* An emission would be somewhat like fig 3b, incase any absorption occurs.

* The $\bar{e}$ while recombining with a hole in VB would emit a photon of same energy that it absorbed to make upward transition from VB to CB.

Absorption and emission in semiconductor

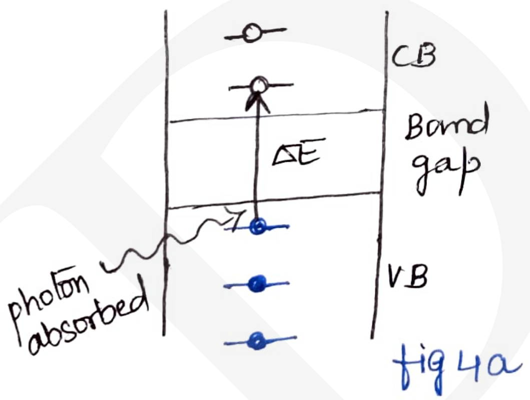

fig 4a

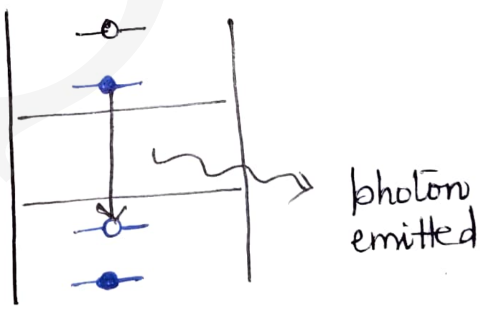

fig 4b

* Light photon is absorbed by an $\bar{e}$ to make an upward transition from VB to CB. The energy of the photon $h\nu$ should be greater than band gap.

$$\boxed{h\nu > E_g}$$

* Most of the semiconductor materials have band gap between 0.6 to 1.8 eV.

* Energy gap corresponding to maximum wavelength i.e. 700 nm (minimum energy) photon would give us minimum Energy –

$$E_{g\,min} = \frac{hc}{\lambda} = \left(\frac{6.6\times10^{-34}\times3\times10^{8}}{700\times10^{-9}}\right) / (1.6\times10^{-19})$$

$$E_{g\,min} = 1.8\ eV$$

* Thus, all the visible light is absorbed by the semiconductor and it appears opaque.

* When an $\bar{e}$ in CB recombine with a hole in VB, photon is emitted as shown in figure 4.b.

Extra

Absorption & Emission in dielectrics.

* Dielectric solids have a wide band gap. Energy levels other than VB & CB can paiticipate in transition.

* Impurity or other electrically active defect can introduce new energy levels within band gap.

* Light radiation of specific wavelengths may be

emitted as a result of $\bar{e}$ transitions involving these levels within the band gap as shown in fig 5b.

* Photon emission could be multistep (5a) or phonon & photon emission can complete the transition as shown in fig 5c.

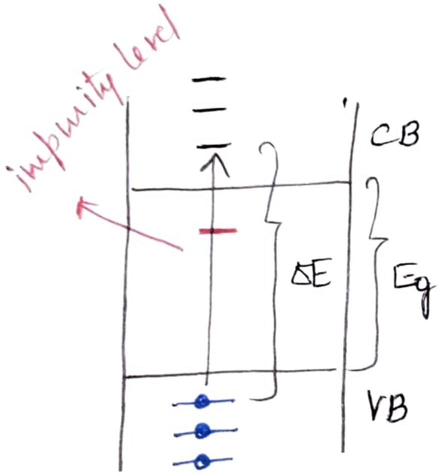

fig 5a

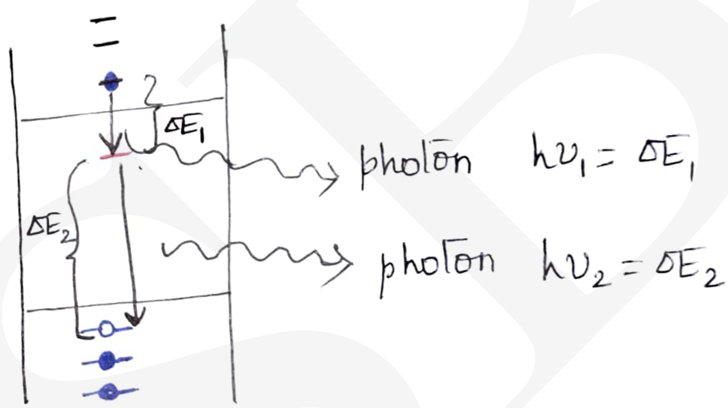

fig 5b.

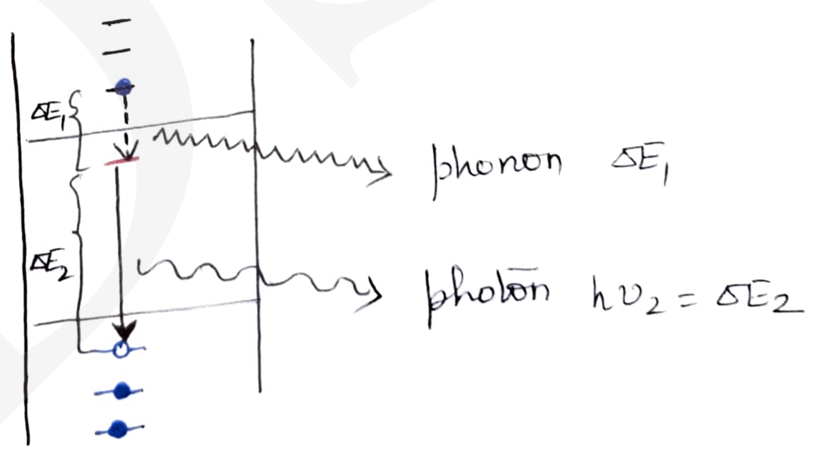

fig 5c.