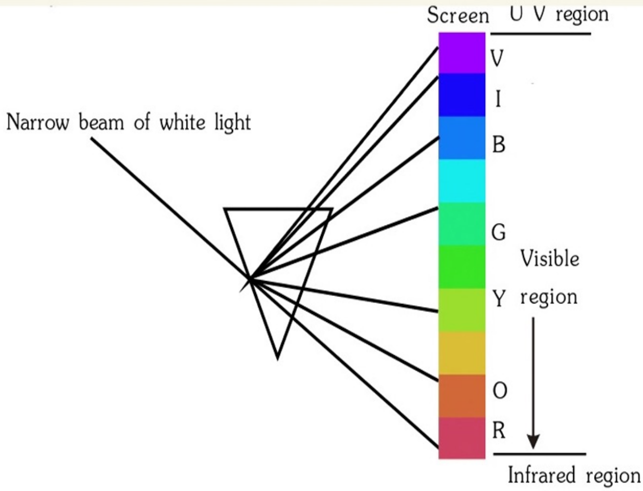
VMC Vidyamandir Classes SINCE 1986

IIT JEE | MEDICAL | FOUNDATION

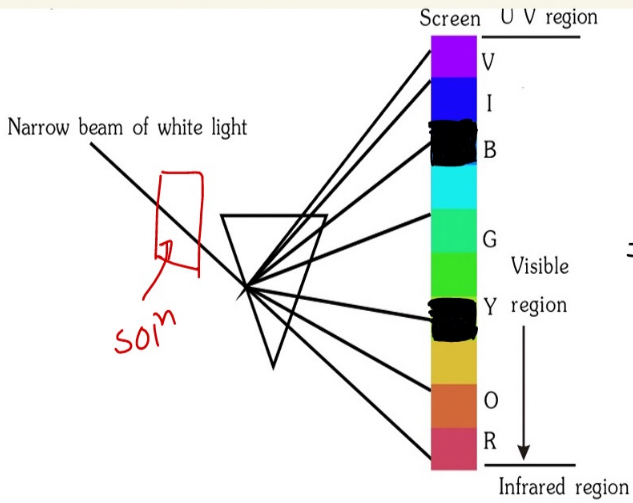
Atomic structure

(iii) **Continuous and discontinuous spectra :** A continuous spectra is that which contains all the wavelength lying in a particular region of spectra. e.g., VIBGYOR indicates a continuous spectra in visible region.

On the other hand, if some wavelengths are missing and spectra contain certain wavelengths, it is called discontinuous spectra. e.g., VBYR is discontinuous spectra in which I, G & O wavelengths are missing from visible radiation.



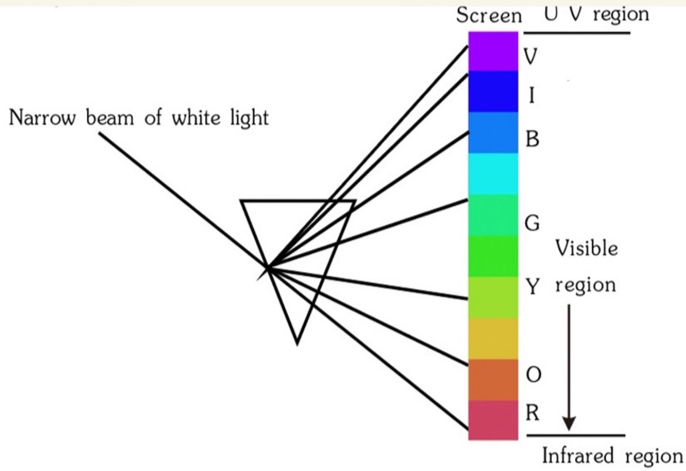
⇒ Continuous Spectrum



⇒ Discontinuous Spectrum

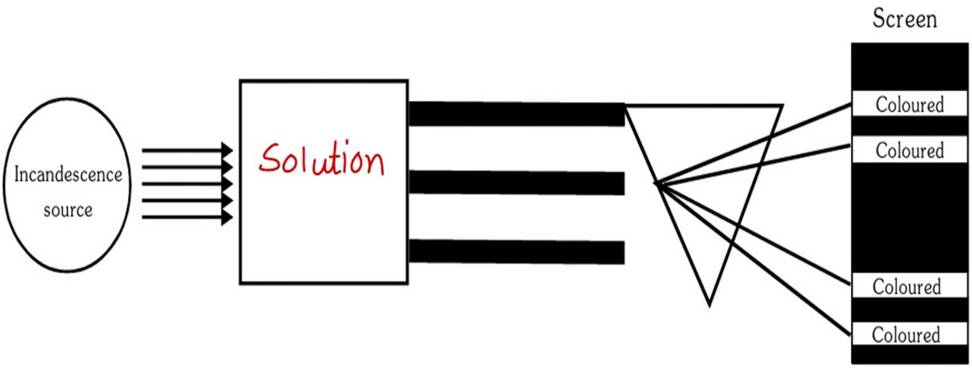
Emissions spectrum :

When the radiation emitted from incandescence source (eg. from the candle, sun, tubelight, burner, bulb, or by passing electric discharge through a gas at low pressure, by heating some substance at high temp) is passed directly through the prism and then received on the screen then the obtained spectrum is called as emission spectrum.



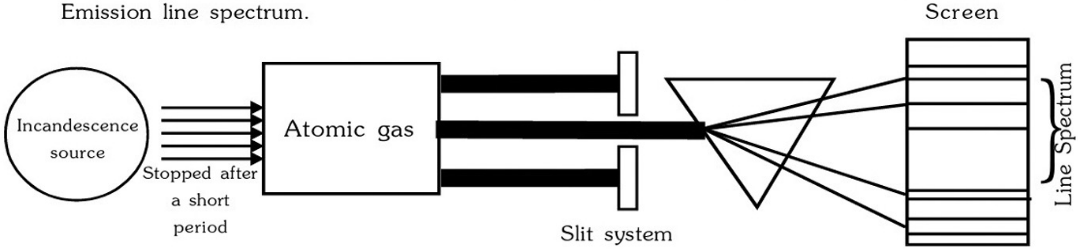
Absorption spectrum :

When white light is first passed through a solution or vapours of chemical substance and then analyzed by spectroscope, it is observed that some dark lines are obtained in otherwise continuous spectrum. This type of spectrum is called as Absorption spectrum.



line spectrum :

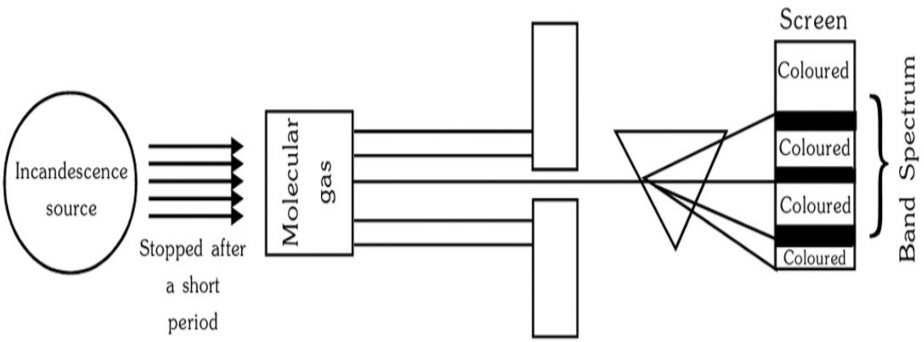
When an atomic gas is raised to incandescence source or subjected to electrical excitation, it first absorbs energy & then gives it out as radiation. On examining these radiation through a spectroscope a spectrum is obtained which have well defined lines,each corresponding to a definite wave length & these lines are separated from each other by dark space. This type of Emission spectrum is called as Emission line spectrum.



band spectrum :

If molecular form of the gas is used, it first absorbs energy for not only electron transition but for rotational, vibrational and translational then emits radiations.

On examining these radiations through a spectroscope a spectrum is obtained on the screen, which are group of closely packed lines called Bands, therefore this type of Emission spectrum is called as emission band spectrum. Bands are separated from each other by dark space.



Note : Since band spectrum are caused by molecules therefore band spectrum are also called as molecular spectrum.

Limitations of electromagnetic wave theory →

This theory explains the properties of light such as interference and diffraction etc. but it could not explain

(i) Photoelectric effect

(ii) Black body radiation

(iii) The line spectrum of atoms

(iv) Variation of heat capacity of solids as a function of temperature.

Particle nature of EMR (Planck's quantum theory) →

According to this theory, Energy is not emitted or absorbed continuously but it is emitted or absorbed in the form of small Packets (bundles). Each small Packet of energy is called as quantum. In case of light, quantum of energy is called photon.

According to this theory,

$$E \propto \nu$$

$$\Rightarrow \boxed{E = h\nu = \frac{hc}{\lambda}}$$

Where E = Energy of one photon

h = Planck constant

$= 6.62 \times 10^{-34}$ J-sec.

$\nu \rightarrow$ frequency

$c \rightarrow$ speed of light $= 3 \times 10^{8}$ m/sec.

$\lambda \longrightarrow$ Wavelength.

$$\boxed{hc = 1240\ eV\text{–}nm = 12400\ eV\text{–}A^{\circ}}$$

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

$$\boxed{\text{Total amount of energy transmitted} = nh\nu = \frac{nhc}{\lambda}}$$

Where n = no. of photons
$(1, 2, 3, 4, ----)$

How many photons are emitted per second by a 5 mW laser operating at 620 nm?

$$5\,mW = 5\,mJ \text{ per sec.}$$
$$= 5 \times 10^{-3}\ J \text{ per sec.}$$

$$5 \times 10^{-3}\ J = n \times \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{620 \times 10^{-9}}$$

$$n = \frac{5 \times 620 \times 10^{-12}}{6.62 \times 3 \times 10^{-26}} = 1.56 \times 10^{16}$$

The eyes of a certain member of the reptile family pass a visual signal to the brain when the visual receptors are struck by photons of wavelength 850 nm. If a total energy of 3.15×10^{-14} J is required to trip the signal, what is the minimum number of photons that must strike the receptor. ($h = 6.6 \times 10^{-34}$)

$$3.15 \times 10^{-14} = \frac{n \times 6.6 \times 10^{-34} \times 3 \times 10^{8}}{850 \times 10^{-9}}$$

One quantum is absorbed per gaseous molecule of Br_2 for converting into Br atoms. If light absorbed has wavelength 5000 Å, calculate energy required in kJ/mol.

Solⁿ →

$$1 \ Br_2 \text{ molecule} \longrightarrow 1 \text{ Photon}$$

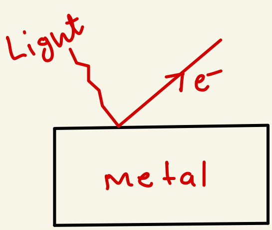
$$1 \text{ mole } Br_2 \longrightarrow N_A \text{ Photon}$$

$$E_T = \frac{6\times10^{23} \times 6.62\times10^{-34} \times 3\times10^{8}}{5\times10^{-7}}$$

$$= 23.83 \times 10^{4} \ J/mol$$

$$= 238.3 \ kJ/mol$$

Photo electric effect → It is the phenomenon of ejection of e^- from the surface of metal when ligut of suitable frequency strikes the metal surface. The ejected e^-s are called photoelectrons.



Energy of striking Photon = Min. energy reauired to eject photo e^- + K.E. of photo e^-

$$E_i = \phi + K.E.$$

$$\boxed{\begin{aligned} h\nu &= h\nu_0 + K.E. \\ \frac{hc}{\lambda} &= \frac{hc}{\lambda_0} + K.E. \end{aligned}}$$

where $h \longrightarrow$ planck const. $= 6.62 \times 10^{-34}$ J-sec.

$c \longrightarrow$ speed of light $= 3 \times 10^8$ m/sec

$\nu \longrightarrow$ Frequency of striking Photon

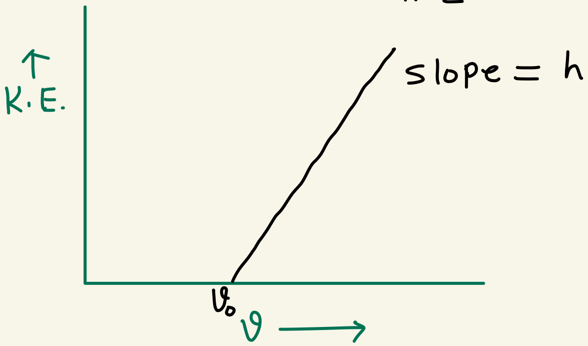
$\nu_0 \longrightarrow$ Threshold frequency
(min. frequency of Photon required to eject a photo e^-)

$\phi \longrightarrow$ work function
(min. energy reauired to eject a photo e^-)
It is diff. for diff. metals.

$\lambda \longrightarrow$ wavelength of striking Photon

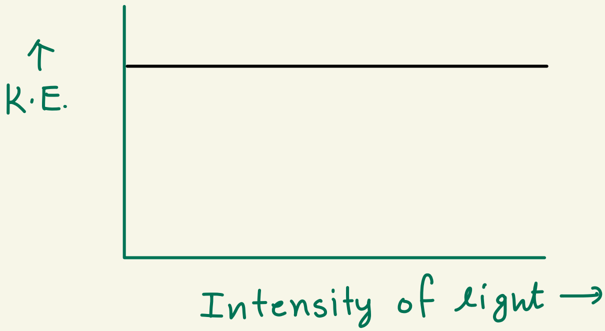
$\lambda_0 \longrightarrow$ Threshold wavelength
(Max. wavelength of photon reauired to eject a photo e^-)

$K.E. = h\nu - h\nu_0$



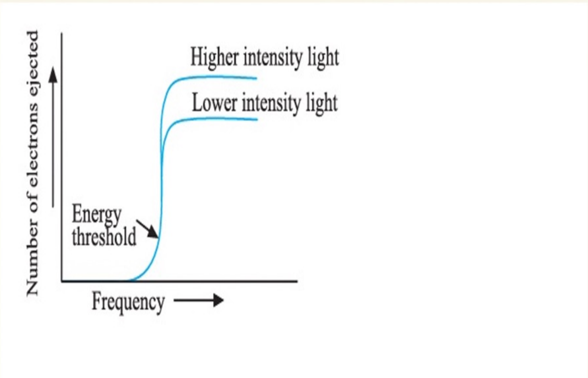
Y- intercept $= -h\nu_0$

X - intercept $= \nu_0$



Intensity of light $\propto$ No. of photons

$\propto$ No. of photo e^- ejected



Stopping Potential (V_0) $\longrightarrow$ The min. Potential at which Photoelectric current becomes zero is called stopping Potential.

Change in K.E. = work done by stopping Potential

$$0 - K.E. = (-e) \cdot V_0$$

$$K.E. = eV_0$$

$$h\nu = h\nu_0 + eV_0$$

$$\boxed{\text{Stopping Potential} \quad V_0 = \frac{h}{e}(\nu - \nu_0)}$$

Note → Photoelectric effect takes place when

(i) $\nu \geq \nu_0$

(ii) $\lambda \leq \lambda_0$

(iii) $E_i \geq \phi$

12. *If the frequency of light in a photoelectric experiment is doubled, the stopping potential will :*

(A) *be doubled*
(B) *be halved*
(C) *become more than double* ✓
(D) *become less than double*

Sol^n →

$$V_0 = \frac{h}{e}(\nu - \nu_0)$$

$$V_0' = \frac{h}{e}(2\nu - \nu_0)$$

$$\frac{V_0'}{V_0} = \frac{2\nu - \nu_0}{\nu - \nu_0} > 2$$

Illustration - 4 *A photon of light with $\lambda = 400$ nm falls on a metal surface. As a result, photoelectrons are ejected with a velocity of 6.4×10^5 m/s. Find :*

(a) *the kinetic energy of emitted photoelectrons,* (b) *the work function (in eV) of the metal surface.*

Sol^n →

(a) $$K.E. = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times (9.1 \times 10^{-31}) \times (6.4 \times 10^5)^2$$

$$= 1.86 \times 10^{-19} \text{ J}$$

$$= \frac{1.86 \times 10^{-19}}{1.6 \times 10^{-19}} = 1.16 \text{ eV}$$

(b) $$E_i = \phi + K.E.$$

$$\frac{1240}{400} = \phi + 1.16$$

$$\phi = 1.94 \text{ eV}$$

Q. The work function (ϕ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300 nm wavelength falls on the metal is **JEE 2011**

Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
ϕ (eV)	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

$\underline{\text{Sol}^n \rightarrow}$

$$E_i = \frac{hc}{\lambda} = \frac{1240 \text{ eV-nm}}{300 \text{ nm}}$$

$$= 4.13 \text{ eV}$$

Photoelectric effect takes place when

$$E_i \geq \phi$$

Li, Na, K, Mg will show Photoelectric effect.

10. *When a certain metal was irradiated with light of frequency 3.2×10^{16} Hz, photoelectrons emitted had twice the kinetic energy as did photoelectrons emitted when the same metal was irradiated with light of frequency 2.0×10^{16} Hz. Hence threshold frequency is :*

(A) 0.8×10^{15} Hz (B) 8.0×10^{15} Hz (C) 0.8×10^{14} Hz (D) 6.4×10^{16} Hz

$\underline{\text{Sol}^n \rightarrow}$

$$h\nu - h\nu_0 = K.E.$$

$$h(3.2 \times 10^{16} - \nu_0) = 2K \quad \text{——— (1)}$$

$$h(2 \times 10^{16} - \nu_0) = K \quad \text{——— (2)}$$

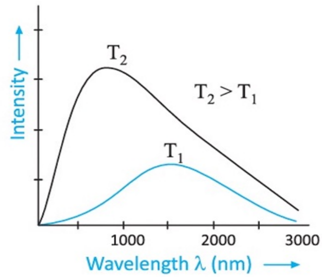
(1) ÷ (2)

$$\frac{3.2 \times 10^{16} - \nu_0}{2 \times 10^{16} - \nu_0} = 2$$

$$\nu_0 = 8 \times 10^{15} \text{ Hz}$$

BLACK BODY RADIATION (1900)

- In 1900, Max Planck was the first to give a concrete explanation for the phenomenon of black body radiation. According to the Plank's quantum theory, an ideal body is a perfect absorber and perfect emitter of radiation and called a black body.
- When such a body is heated it emits radiation over a wide range of wavelengths. For instance, when an iron rod is heated in a furnace, it firstly turns dull red, then progressively becomes more and more red as the temperature increases. On heating further, the radiation emitted becomes white and then blue as the temperature becomes very high.
- In terms of frequency, it means that radiation emitted goes from a lower frequency to higher frequency as the temperature increases. The red colour lies in the lower frequency area whereas blue light lies in the higher frequency area of the electromagnetic spectrum.
- The exact frequency distribution of emitted radiation from a black body depends only on its temperature. At a given temperature, the intensity of radiation increases with decrease in wavelength, reaches a maximum value at a given wavelength and then starts decreasing with further decrease in wavelength as shown in the figure below.



- Planck explained that atoms and molecules could emit (or absorb) energy only in discrete quantities (quantum) and not in anarbitrary manner as was believed at that time.

Bohr's atomic model → It is based on Planck's quantum theory of radiation. It explains stability of atoms and line spectrum of atoms.

Postulates →

(1) The e^-s in an atom revolve around the nucleus only in circular path having fixed energy, called orbits or shells or energy levels or stationary states.

(2) The angular momentum of an e^- in a given orbit is given by —

$$\boxed{L = mvr = \frac{nh}{2\pi}}$$

(3) So long an e^- revolves in a given orbit, it neither absorbs nor emits any energy.

(4) When an e^- jumps from one orbit to another orbit then it either emits or absorbs some amount of energy.

Lower orbit $\longrightarrow$ Higher orbit $\Rightarrow$ Energy is absorbed

Higher orbit $\longrightarrow$ lower orbit $\Rightarrow$ Energy is emitted

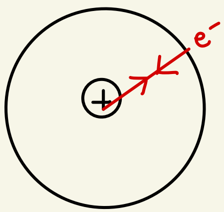
Energy absorbed or Energy emitted	$\Delta E = h\nu = \frac{hc}{\lambda}$ $= E_{high} - E_{low}$

where E_{high} = energy of higher energy level

E_{low} = energy of lower energy level

Advantages of Bohr's atomic model →

(1) Calculation of velocity of e^- in an orbit →



$$\left|\frac{K q_1 q_2}{r^2}\right| = \left|\frac{mv^2}{r}\right|$$

$$\left|\frac{K(ze)(-e)}{r^2}\right| = \left|\frac{mv^2}{r}\right|$$

$$\frac{Kze^2}{r^{\cancel{2}}} = \frac{mv^2}{\cancel{r}}$$

$$\frac{Kze^2}{r} = mv^2 \quad \text{———} \quad (1)$$

$$mvr = \frac{nh}{2\pi} \quad \text{———} \quad (2)$$

$$\cancel{m}\cancel{v} \frac{Kze^2}{\cancel{m}v^{\cancel{2}}} = \frac{nh}{2\pi}$$

$$v = \frac{2\pi Kze^2}{nh} \quad \text{———} \quad (3)$$

$$\Rightarrow \boxed{v = 2.19 \times 10^6 \frac{z}{n} \ m/sec.}$$

(2) Calculation of radius of an orbit →

By Putting the value of v from eqⁿ (3) in eqⁿ (2)

$$m\left(\frac{2\pi K z e^2}{nh}\right) r = \frac{nh}{2\pi}$$

$$r = \frac{n^2 h^2}{4\pi^2 m K z e^2}$$

$$\boxed{r = 0.529 \times \frac{n^2}{z} \ A^\circ}$$

where z = atomic no.

n = orbit no.

(3) Calculation of K.E., P.E., T.E. →

$$K.E. = \frac{1}{2} m v^2 = \frac{1}{2} \frac{K z e^2}{r}$$

$$P.E. = \frac{K q_1 q_2}{r} = \frac{K (ze)(-e)}{r}$$

$$P.E. = -\frac{K z e^2}{r}$$

$$T.E. = K.E. + P.E. = -\frac{1}{2} \frac{K z e^2}{r}$$

$$T.E. = -\frac{1}{2}\frac{Kze^2}{n^2h^2} \times 4\pi^2 mKze^2$$

$$\boxed{\begin{aligned} T.E. &= -2.18 \times 10^{-18} \times \frac{z^2}{n^2}\ J/atom \\ T.E. &= -13.6\ \frac{z^2}{n^2}\ eV/atom \end{aligned}}$$

$$\boxed{T.E. = -K.E. = \frac{P.E.}{2}}$$

Homework

DTS-1 to 11
Q.1-7,9,17-20,22,24,26-28,31,33,36-38,42-44,91,92,94,98,99, 117,119,126

JEE MAIN ARCHIVE:
Q.1,12,25,32,34,39

JEE ADVANCED ARCHIVE:
Q.1-3,5-7,10,15-18,20-22,24,26,29,33,52,56,66