BHARAT SHIKSHAN SANSTHA

Shri Chhatrapati Shivaji College Omerga.

Prepared by
Mr. B.T. Vhanale
Dept of Chemistry

Elementary Quantum Mechanics

Content:-

1. Black body radiation
2. photoelectric effect
3. Bohr's modes of hydrogen atom (no derivation) and its defects.
4. Compton effect
5. De Broglie Hypothesis
6. The Heisenberg’s uncertainty principles
7. Harmiltonian operator

Introduction

- Quantum mechanics is describes the physical properties of nature at the scale of atoms & subatomic particles.
- It is proposed by Max Plank & applied by Einstein & Bohr.
- This theory is based on the postulates that all interactions between matter & radiation occur 'Quanta'.

Black Body Radiation

- Black body radiation is the radiation emitted by a non-reflecting solid body.
- A perfect black body is one which absorbs all the radiation falling on it.
- Experimentally, a hollow body, blackened on the inside and with a small opening, is considered a typical black body.
- Any radiation that enters through the small opening is reflected repeatedly from the walls until all of the energy eventually becomes absorbed.
- A back body is both a good absorber and radiator of energy. Of the various types of bodies heated to particular temperature, only black body, radiates the maximum amount of energy. It radiates the same amount of energy as it absorbs.

The main aspects of black body radiation which emerge from experimental observations, are:

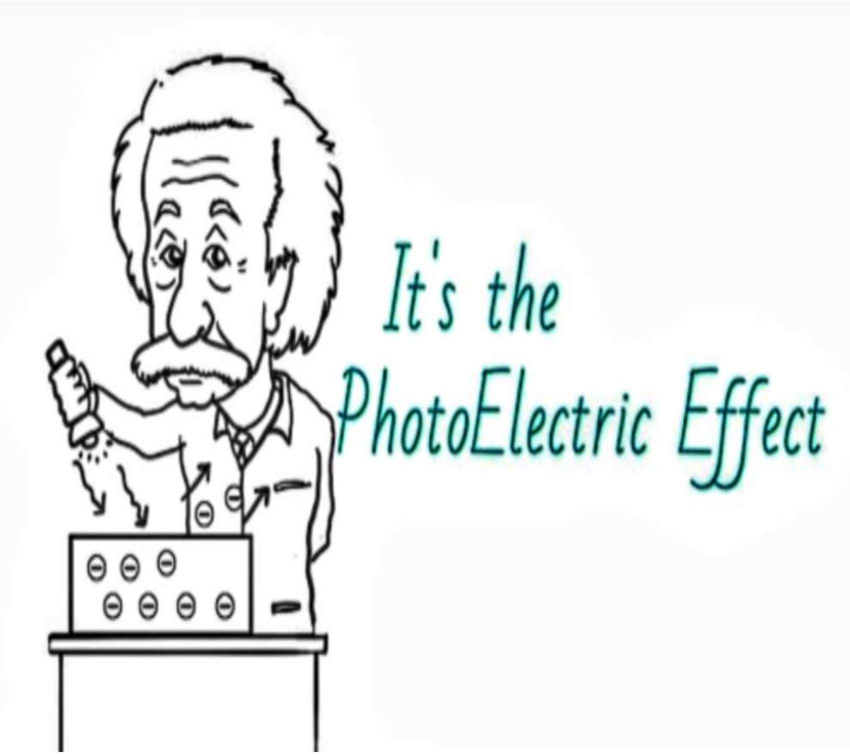
i) At shorter wavelength region, that is at higher frequency region, intensity of radiation is low.

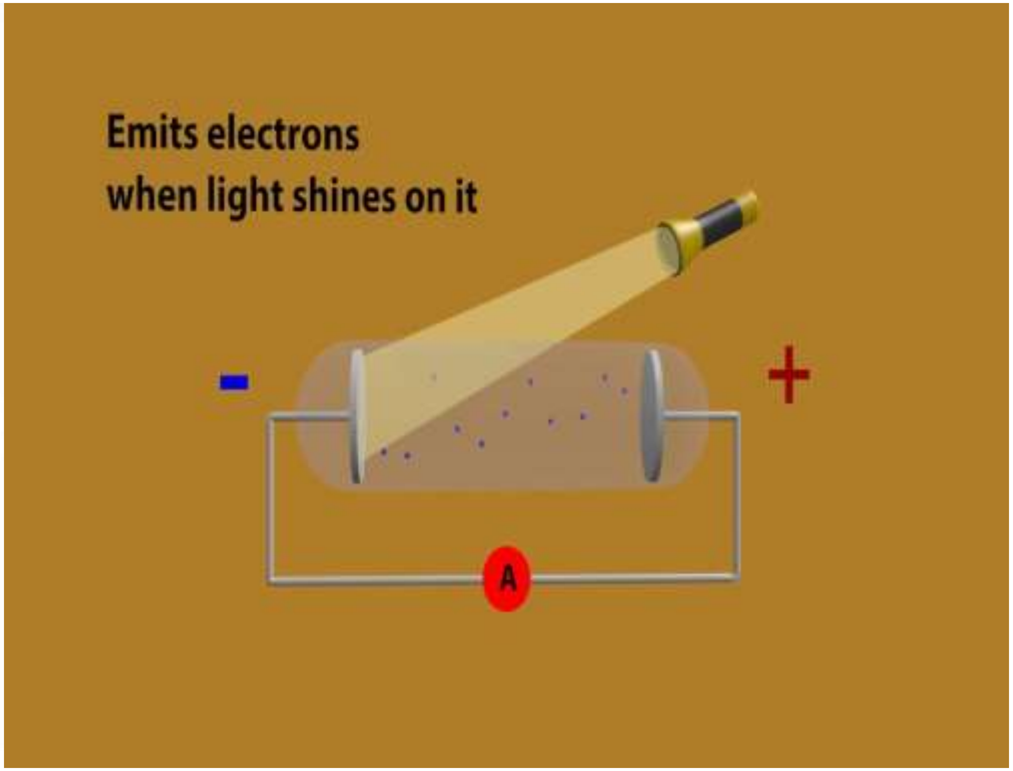
ii) At every temperature, there is a wavelength at which energy radiated is maximum. This wavelength is called λ_{max} value of that temperature.

iii) At higher temperatures, there is increased intensity of radiation in the shorter wavelength region.

Photoelectric Effect

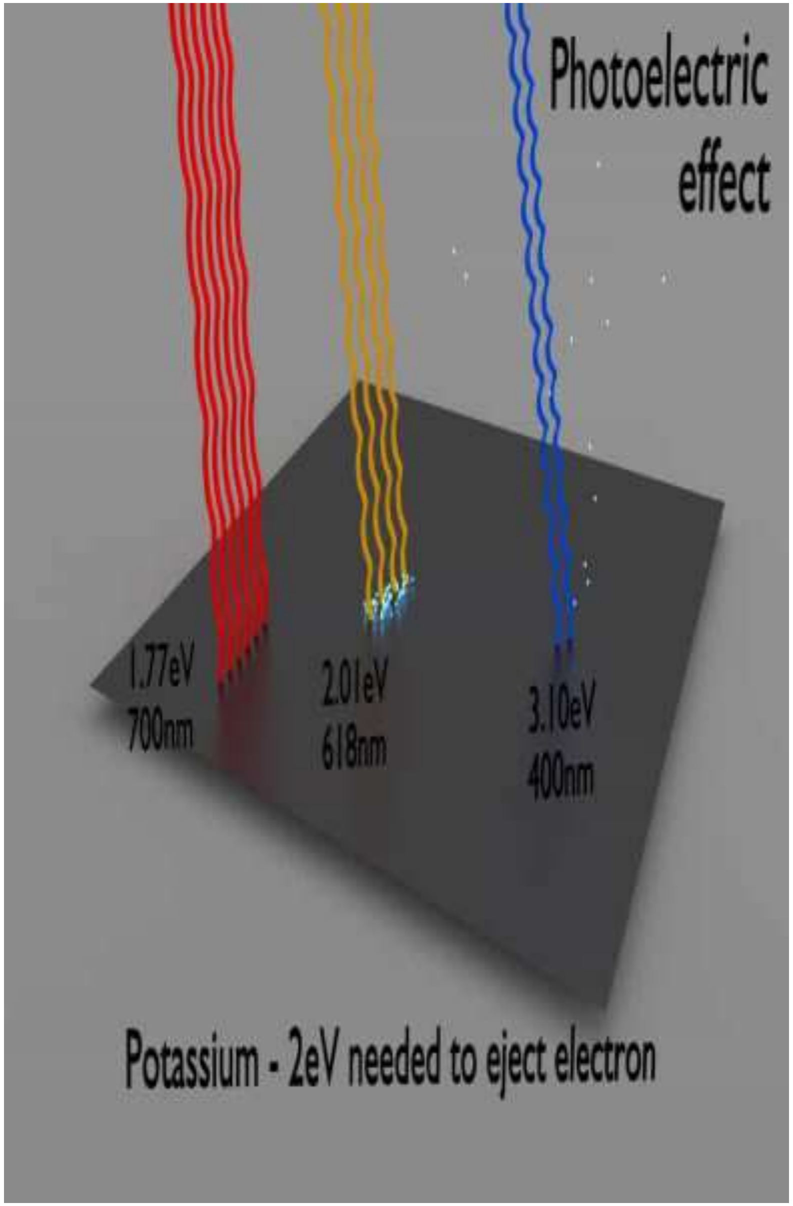
- The emission of electrons when metals are irradiated with ultraviolet light is known as photoelectric effect.
- The main feature of this phenomenon is that a minimum frequency of light is known as threshold frequency (υ_o), is required to emit photoelectrons.





Conclusion

- If the frequency of the light is constant, the photoelectric current increases with increasing intensity of the light.
- The photoelectrons are released within less than 10^{-9} sec after the surface is illuminated by the light. The emission is essentially instantaneous with illumination.
- For a given photosensitive surface, the emission of the photoelectrons takes place only if the frequency of the light is equal to a greater than a certain minimum frequency υ_o, sometimes called the threshold frequency. The value of υo is different for different materials.
- he maximum kinetic energy (k_{max}) of the photoelectrons is independent of the intensity of incident radiation.
- The maximum kinetic energy (k_{max})of the photoelectrons depends on the frequency of the incident light.
- The relationship between k_{max} and υ_o is linear.



Bohr's modes of hydrogen atom

- Bohr’s suggested that perhaps the electron could only orbit the nucleus in specific orbit or shells with fixed radius.

- Only those shells with a radius provided by the equation below were allowed, and it was impossible for electrons to exist between these shells.

- Mathematically, the allowed value of the atomic radius is given by the equation $r(n)=n2\times r(1)$ Where n is a positive integer and r(1) is the smallest allowed radius for the hydrogen atom also known as the Bohr’s radius.

- The Bohr’s radius has a value of $r(1)=0.529\times 10-10m$.

- By applying his postulates and the classical laws of physics Bohr workout on various expressions for uni-electronic species like H, H^{+}, $Li^{+,-}$,these expressions are given for radius of nth orbit velocity and energy of an electron which is revolving around the n^{th} orbit.
- He also derived an expression for the frequency (υ)and wavelength (λ)of the spectral line estimated when an electron falls from a high energy orbit to low energy orbit.

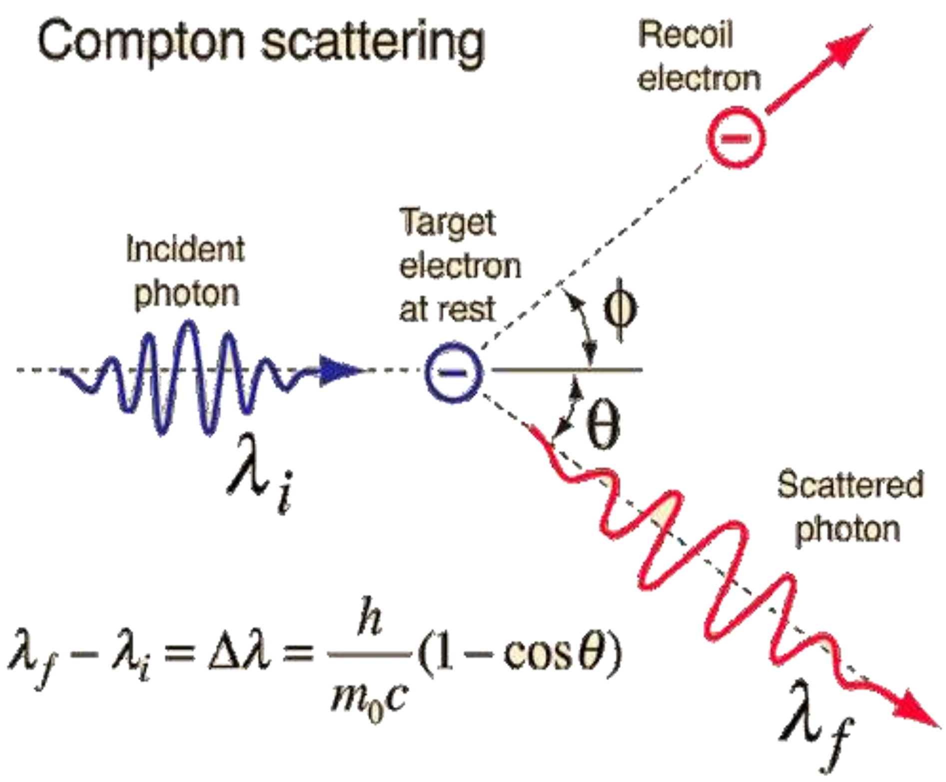
Defects of Bohr’s Model:

- Bohr’s model doesn’t work well for complex atoms.
- It couldn’t explain why some spectral lines are more intense than others.
- It could not explain why some spectral lines split into multiple lines in the presence of a magnetic field.
- The Heisenberg’s uncertainty principle contradicts Bohr’s idea of electrons existing in specific orbits with a known radius and velocity.

Compton effect

- In 1923,A. M. Compton found that when X- Rays of high energy are allowed to fall on solid matter like carbon block or some other light elements, an electron is ejected from the carbon block and X-Rays are scattered from their original path.

- In this process a proton from the incident X-Ray collides while the loosely bound electron in the carbon block. After receiving an impact from the photon, the electron which was initially at restgain some velocity and hence moves below the direction of incident X-Rays while the photon is deflected above.



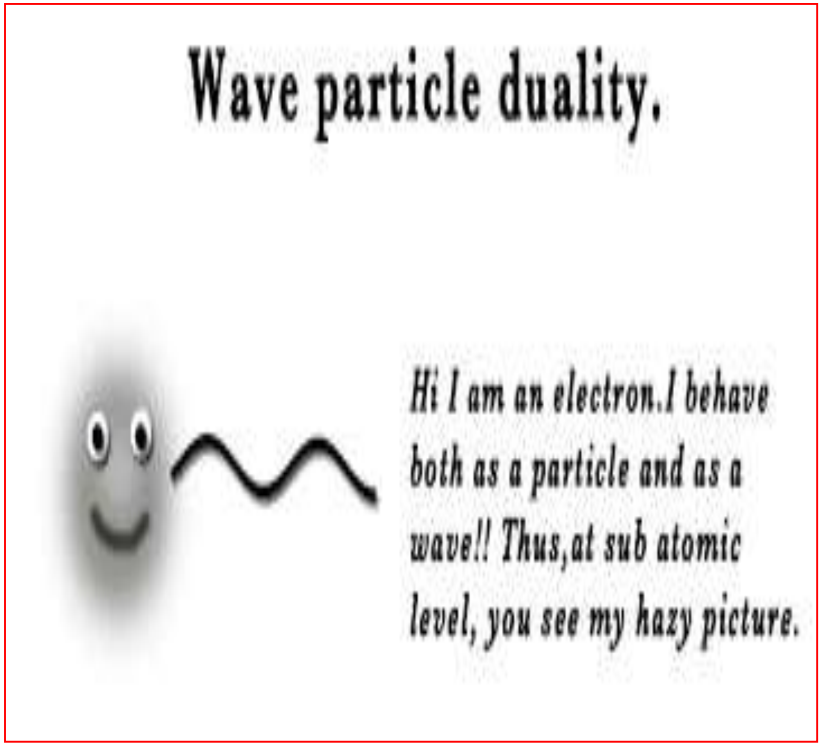
If the wavelength of incident X-Ray and scattered X-Ray are λ and λ' respectively then hc/λ and hc/λ’ are the energy associated with the photon of incident and scattered reflect respectively thus the decrease is energy is equal to - hc/λ - hc/λ’

“This phenomenon in which there is a change in the wavelength of the scattered X-Ray is called as Compton effect”.

De Broglie Hypothesis

- Einstein in 1905 suggested that light shows dual character, i.e. particle as well as wave nature.
- de-Broglie in 1923 extended Einstein's view and said that all the forms of matter like electrons,protons, neutrons, atoms, molecules, etc. also show dual character, he further said that wavelength (λ) of the moving particles of mass m and velocity vis given by

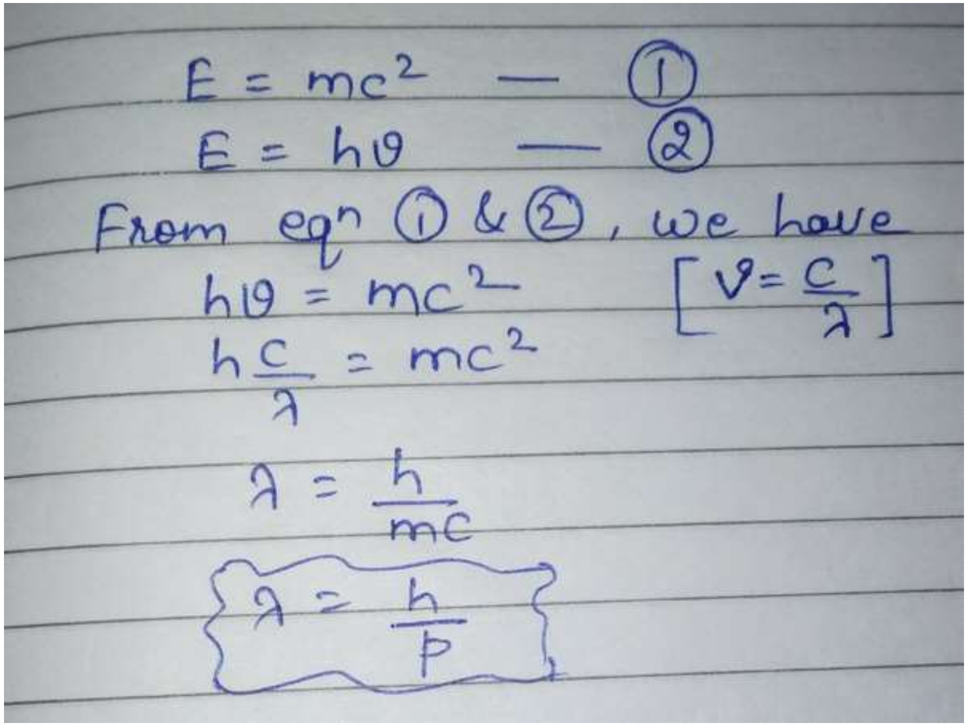
$$\lambda = \frac{h}{mv}$$



This equation is called as de-Broglie's wave equation and λ is called de-Broglie's wavelength.

Where, h = Planck 's constant
m = mass of electron
υ = velocity of electron

de-Broglie’s wave equation:



Einstein's equation: $\mathrm{E} = mc^2$

Planck's equation: $\mathrm{E} = hf$

Equating both, we get

$$mc^2 = hf$$

We know that $f = \frac{c}{\lambda}$

$$mc^2 = \frac{hc}{\lambda}$$

$$mc = \frac{h}{\lambda}$$

or, $$\lambda = \frac{h}{mc}$$

For macroscopic objects, velocity "v" can replace speed of light "c"

Thus our equation becomes:

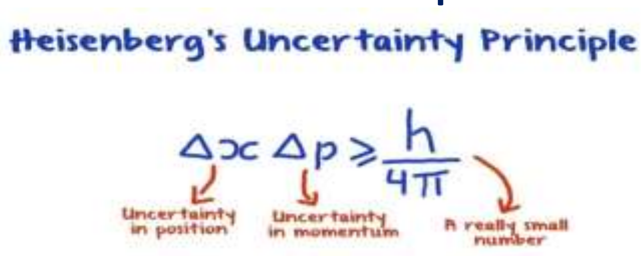
$$\lambda = \frac{h}{mv}$$

Now, $mv = p$ (momentum of particle) and therefore,

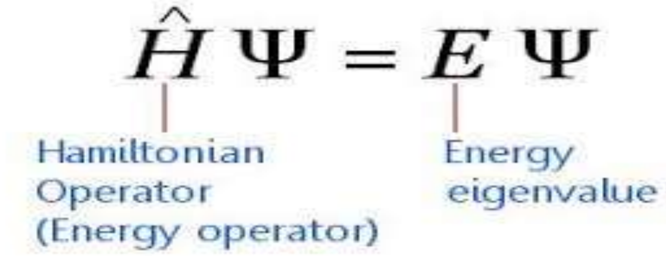
$$\lambda = \frac{h}{p}$$

Heisenberg's uncertainty principles

According to this principle it is not possible to determine simultaneously and precisely both the position and momentum (or velocity) of a microscopic moving particle like electron, proton etc. Thus from the above discussion Heisenberg gives a mathematical treatment which can be expressed as:



Harmiltonian operator



Where, Hϕ is called as Hamiltonian operator. In this equation, ϕ is called Eigenfunction and E is called Eigenvalue.Such an equation is, therefore, called Eigenvalue equation. Thus for Schrodinger wave equation, we can write as given:

(Energy operator) x (wave function) = (energy) x (wave function)