Quantum Mechanics

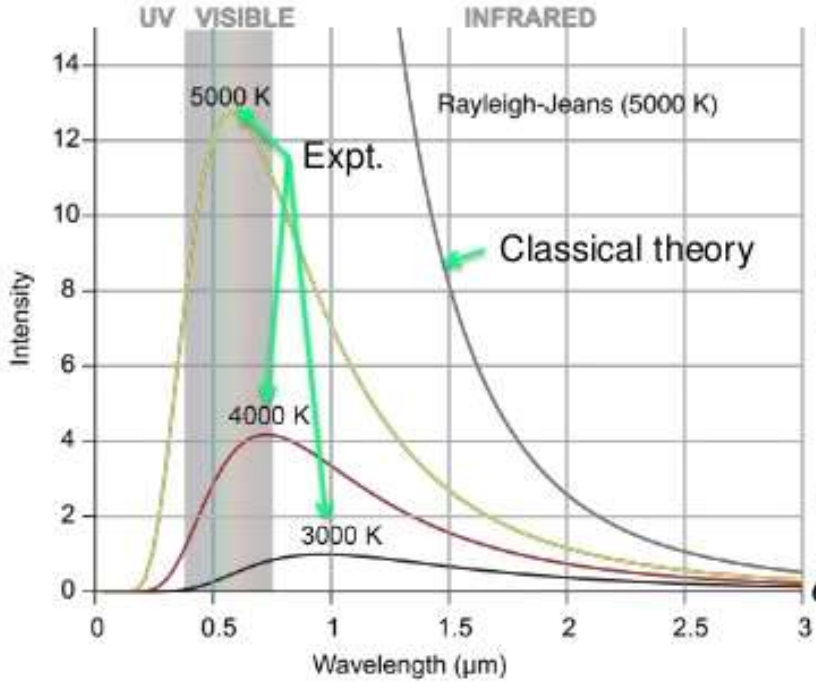
Topic: Origin of Quantum Theory

Covered Topics

- Black Body Radiation
- Photoelectric Effect
- Atomic Spectra
- Particle and Wave

Origin of Quantum Theory: Black Body Radiation

Black body radiation: when objects are heated, maximum wavelength of radiation shifts to shorter wavelengths.



Classical: Rayleigh-Jeans law

$$d\rho(\nu,T) = \frac{8\pi k_B T}{c^3}\nu^2 d\nu$$

Planck (1900): Energies of oscillations in the black body are discrete or *quantized*!

$$E = nh\nu$$

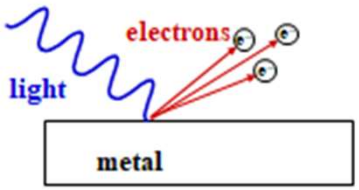
Planck's constant

Planck distribution law:

$$d\rho(\nu,T) = \frac{8\pi h}{c^3}\frac{\nu^3 d\nu}{e^{h\nu/k_B T}-1}$$

Photoelectric Effect- The Nature of Light

Photo-electric Effect – Classical Theory – Light is a wave.



Experimental results

Shine light of one color on metal –
electrons come out with a certain speed.

Increase light intensity
get more electrons out with identical speed.

Tune frequency far enough to red
no electrons come out.

Low Intensity - Small Wave

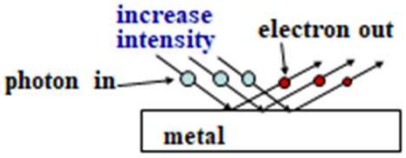
Light wave "hits" electron gently.
Electrons come out – low speed.

High Intensity - Big Wave

Light wave "hits" electron hard.
Electrons come out – high speed.

Einstein explains the photoelectric effect (1905)

Light is composed of small particles – photons.



One photon hits one electron.

Increase intensity – more photons,
more electrons hit – more come out.

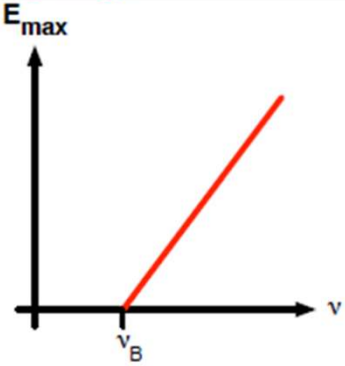
Each photon hits an electron with same impact whether there are many or few.

Therefore, electrons come out with same speed independent of the intensity.

Tune to red, energy to low to overcome binding energy.

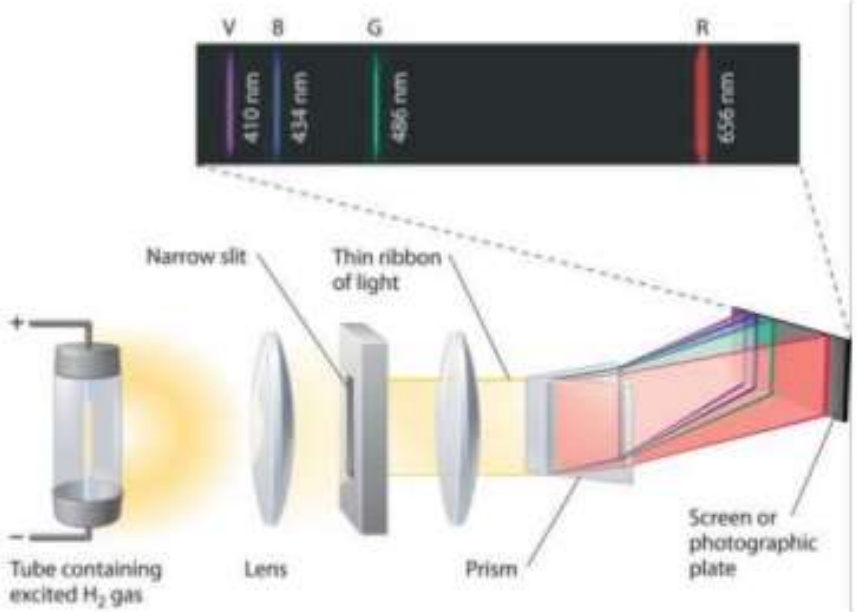
$$K = h\nu - W = h(\nu - \nu_0),$$

$$V_s = \frac{h}{e}\nu - \frac{W}{e} = \frac{hc}{e\lambda} - \frac{W}{e}.$$



Spectrum – Hydrogen Atom

Hydrogen atom line spectrum:



Rydberg (1888) discrete lines of hydrogen spectrum fit formula:

$$\frac{1}{\lambda} = R_{\mathrm{H}} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

where:

$$n_2 > n_1 = 1, 2, 3, 4...$$

Bohr (1911) model:
1) stationary electron orbit,
2) integral # of wavelengths

$$E_n = -\frac{m_e e^4}{8\varepsilon_0^2 h^2} \frac{1}{n^2}$$

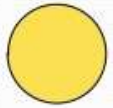
where:

$$n = 1, 2, ...$$

Particle and Wave

Particle

Our traditional understanding of a particle…



"Localized" - definite position, momentum, confined in space

Wave

Our traditional understanding of a wave….

"de-localized" – spread out in space and time.

*Disturbance in the medium

9

References:

1. NouredineZettili,Quantum Mechanics: concepts and applications, 2nd Edition, Wiley, UK, 2009f
2. Introduction to Quantum Mechanics, D.J. Griffith, 2ndEd. 2005, Pearson Education
3. Quantum Mechanics, Robert Eisberg and Robert Resnick, 2ndEd., 2002, Wiley.
4. Quantum Mechanics, Leonard I. Schiff, 3rdEd. 2010, Tata McGraw Hill.
5. Modern Thermodynamics with Statistical Mechanics, Carl S. Helrich, Springer