Old quantum theory

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Quantum Mechanics
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Old quantum theory:

There were two independent formalizim of quantum mechanics

1- Matrix mechanics: This mechanics describe atomic structure starting from observed spectral line. This mechanics inspired from planck's quantization and Bohr's model of Hydrogen atom.

Heisenberg founded his theory on the notation that energy shouldn't be continuous but discrete or quanta. That is same for ~~momentum~~, other mechanical quantities which described by eigen value equation.

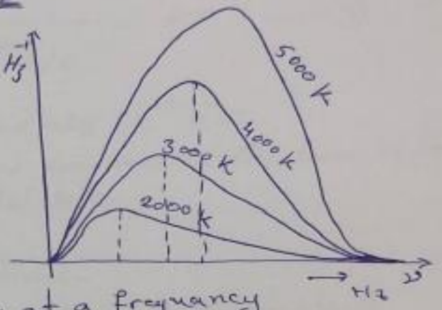
2- wave mechanics: Developed by Schrödinger which is generalization of de Broglie postulate. The formulation describes the dynamics of microscopic matter by means of wave equation (schrödinger equation). In 1927 Max Born adopted probabilistic behavior of wave mechanics $\rho = |\psi|^2$ which interpretated as probability densities.

* Q.M is the theory that describes the dynamics of matter in Microscopic scale.

Black Body radiation

When radiation fall on an object, some of it might be absorbed and some reflected. The ideal black body is absorbs all radiation falling on it. When an object is heated, it radiates electromagnetic energy as a result of thermal agitation of the electrons in its surface and the intensity of radiation depends on its frequency and on the temperature where the emitting light cover the entire spectrum.

the emitted radiation from black body, we need to analyze the spectral distribution of radiation comming out. Figure below shows spectral energy density $U(\nu, T)$ of black body for different temperature as a function of frequency ν.



The experimental results showed that at equilibrium, the emitted radiation has a well-defined, continuous energy distribution, where the energy density neither depends on shape of black body nor on the chemical composition of the object.

The peak of radiation spectrum occures at a frequency that is proportional to the temperature.

Several attempts aimed to understand the origin of continuous spectrum of black body.

* J. Stephan (1879): found experimentally that the total intensity (or the total power per unite surface area) at temperature T is given by:

$$P = \sigma T^4 \quad \text{---} \ (1)$$

which is known as Stefan-Boltzman Law $\sigma = 5.67 \times 10^{-8}\ W m^{-2} K^{-4}$

** Wein's energy density distribution:-

The energy density per unit frequency of emitted black body:

$$U(\nu, T) = A \nu^3 e^{-B\nu/T}, \quad \text{---} \ (2)$$

A, B are empirically defined parameters. The Wein's equation fit well with experimental data at high frequency but fail at low frequency region.

*** Rayleigh's energy density distribution:

Rayleigh's equation for emitted energy density in frequency range ν and $\nu + d\nu$

$$U(\nu, T) = \frac{8\pi\nu^2}{c^3} KT, \quad \text{---} \ (3)$$

where kT is an average energy

we can calculate $\underline{KT}$ from equipartition theorm of classical ③
thermodynamic, all oscillators in the cavity have the same mean
energy

$$\langle E \rangle = \frac{\int_0^\infty E\, e^{-E/kT}\, dE}{\int_0^\infty e^{-E/kT}\, dE} = kT \quad \text{---- (4)}$$

where k is the Boltzman Constant $k = 1.38 \times 10^{-23}\, k^{-1}.J$

As we see from Fig(2), except for low frequancies this law is in Complete disagreement with experimental data.

*** planck's energy density distribution:-

planck considered that the energy of the radiation emitted by the oscillating charges must only come in (integer) multiple of $\underline{\underline{h\nu}}$

$$E = n h\nu \qquad n = 1, 2, 3, ----$$

where h is a planck constant and $h\nu$ is the energy of a "quantum" of radiation. plank's postulation assuming that the energy should be quantized. Accordingly, the correct thermodynamic relation for average energy can be obtained only if we replaced integration in above equation by summation over all discreteness of the oscillators

$$\langle E \rangle = \frac{\sum_{n=0}^{\infty} nh\nu\, e^{-nh\nu/kT}}{\sum_{n=0}^{\infty} e^{-nh\nu/kT}} = \frac{h\nu}{e^{h\nu/kT} - 1}$$

Combining this equation with equation (3), we get:

$$u(\nu, T) = \frac{8\pi\nu^2}{c^3}\, \frac{h\nu}{e^{h\nu/kT} - 1}, \quad \text{---- (5)}$$

Eq(5) known as planck's distribution law.

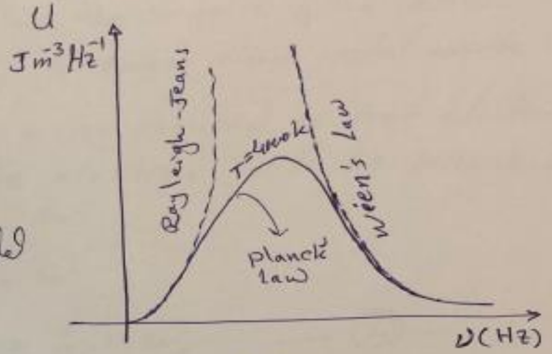
Photoelectric effect

(5) gives exact fit with all experimental radiation distribution. The numerical value of $h = 6.62\times10^{-34}$ J·s ④

Also, we can write above equation in form of wave length rather than frequency.

$$U(\lambda,T) = \frac{8\pi hc}{\lambda^5}\,\frac{1}{e^{hc/\lambda kT}-1} \quad \text{---} ⑥$$

Fig(2): planck's law matches perfectly with experimental distribution data, represented by solid line. However, wien's and Rayleigh law's (dotted line) agree only partially with exprimental data.

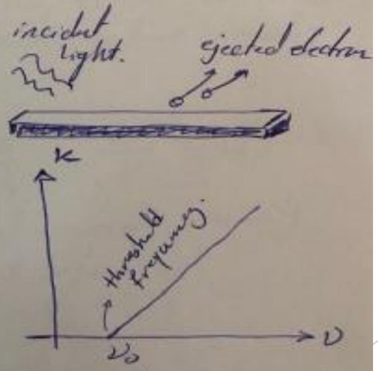


Fig(2)

photo-electric effect

Photo electric effect is ejection of electron from metal when irradiate with light.

* According to the classical mechanics, any frequency with sufficient intensity can supply the necessary energy to ~~the~~ free electron from metal surface as the intensity of light (electromagnetic wave) simply proportional with square of ~~intensity~~ Amplitude.



** Increasing of intensity of light (brightness) alone can in no way dislodge electron from the metal surface. However, by increasing the frequency of the incident radiation beyond threshold even for weak intensity, the emission starts.