An Introduction to Quantum Mechanics

Ankita Ojha
Department of Chemistry
Maharaja College, Arrah

What is Quantum Mechanics

- Classical mechanics (Newton's mechanics) and Maxwell's equations (electromagnetics theory) are mainly applicable for macroscopic systems. Quantum mechanics is used to explain microscopic phenomena such as photon-atom scattering and flow of the electrons in semiconductors.
- QUANTUM MECHANICS is a collection of postulates based on a huge number of experimental observations. The differences between the classical and quantum mechanics can be understood by examining both
  - The classical point of view
  - The quantum point of view

Classical Mechanics

- **A PARTICLE is an indivisible mass point object that has a variety of properties that can be measured, which we call observables. The observables specify the state of the particle (position and momentum).**
- **A SYSTEM is a collection of particles, which interact among themselves via internal forces, and can also interact with the outside world via external forces. The STATE OF A SYSTEM is a collection of the states of the particles that comprise the system.**
- **All properties of a particle can be known to infinite precision.**

Quantum Mechanics

- Quantum particles acts as both particles as well as wave i.e. show Wave-Particle Duality.
- Quantum state is a collection of variety of possible outcomes of measurement of physical properties.
- Quantum mechanics largely depends on the phenomena of probability.
- QUANTIZATION of energy is yet another property of "microscopic" particles.

Heisenberg Uncertainty Principle

- It is impossible to simultaneously specify the values of particle's position and its momentum for a microscopic particle, i.e.
- Position and momentum are, therefore, considered as incompatible variables.

$$\Delta x(t_0) \cdot \Delta p_x(t_0) \geq \frac{1}{2}\frac{h}{2\pi}$$

Particle-Wave Duality

- The behavior of a "microscopic" particle is very different from that of a classical particle:
  - ➔ in some experiments it resembles the behavior of a classical wave (not localized in space)
  - ➔ in other experiments it behaves as a classical particle (localized in space)
- Maxwell's theory of electromagnetic radiation can explain these two phenomena, which was the reason why the other theories of light were discarded.

Basics of Quantum Mechanics
- Particle-Wave Duality -

- Waves as particles:
  - Max Plank work on black-body radiation, in which he assumed that the molecules of the cavity walls, described using a simple oscillator model, can only exchange energy in quantized units.
  - 1905 Einstein proposed that the energy in an electromagnetic field is not spread out over a spherical wavefront, but instead is localized in individual clumbs - quanta. Each quantum of frequency n travels through space with speed of light, carrying a discrete amount of energy and momentum =photon => used to explain the photoelectric effect, later to be confirmed by the *x*-ray experiments of Compton.
- Particles as waves
  - Double-slit experiment, in which instead of using a light source, one uses the electron gun. The electrons are diffracted by the slit and then interfere in the region between the diaphragm and the detector.

Blackbody Radiation

- Given by Max Planck (1858-1947).
- When a material is heated, it radiates heat and its color depends on its temperature
- Example: heating elements of a stove:
  - Dark red: 550ºC
  - Bright red: 700ºC
  - Then: orange, yellow and finally white (really hot !)
- The emission spectrum mainly depends on the material.

Blackbody

- A material is constantly exchanging heat with its surrounding (to remain at a constant temperature).
- A blackbody is a perfect absorber. Incoming radiations is totally absorbed and none is reflected