

Modern Physics

1. atomic structure,
2. quantum mechanics,
3. photoelectric effect,
4. relativity,
5. nuclear physics

Learning Objectives

1. Details of atomic structure- you already know
2. Details of atomic structure- you don't know
3. What is quantum mechanics?

References: 1) Quantum Physics by H.C. Verma
2) Concepts of Modern Physics by Arthur Beiser

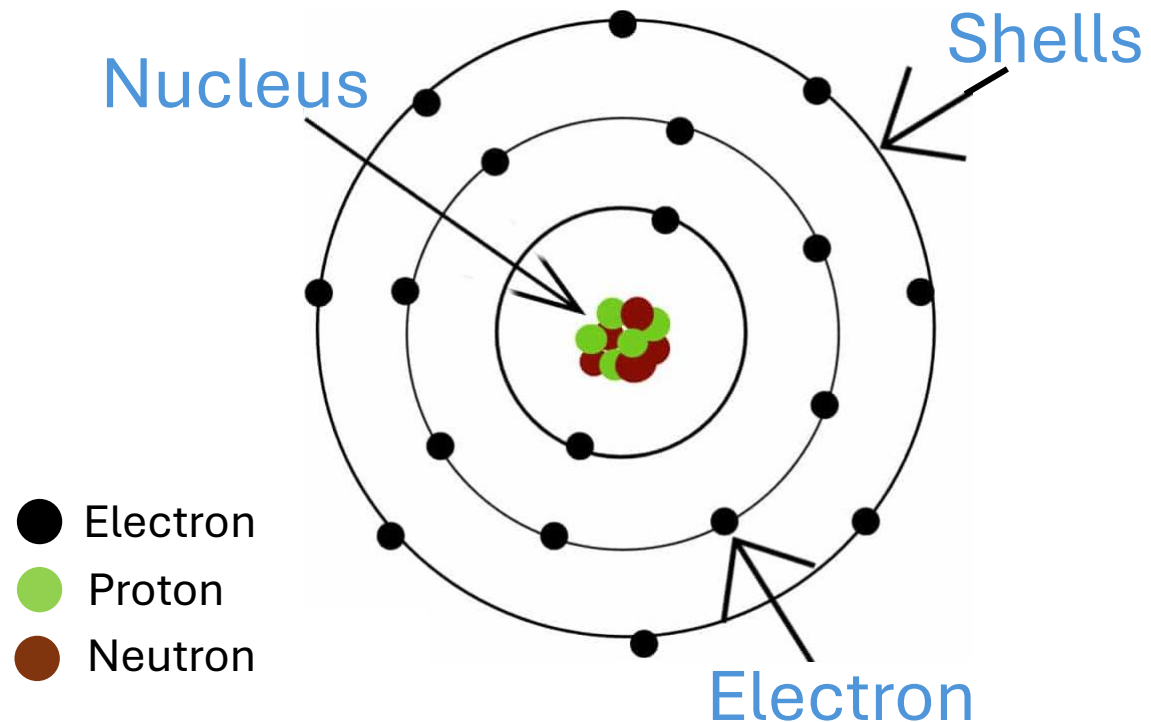
Atomic structure: From your previous class

1. What is an atom?

Building block of matter

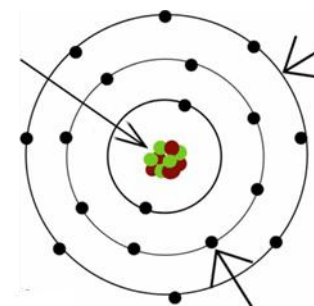
Model of the Atom

Bohr's model of atom



Atomic structure: Bohr's model of atom

1. Bohr's first postulate was that an electron in an atom could revolve in certain stable orbits without the emission of radiant energy, contrary to the predictions of electromagnetic theory. According to this postulate, each atom has certain definite stable states in which it can exist, and each possible state has definite total energy. These are called the stationary states of the atom.
2. Bohr's second postulate defines these stable orbits. This postulate states that the electron revolves around the nucleus only in those orbits for which the angular momentum is some integral multiple of $h/2\pi$ where h is the Planck's constant ($= 6.6 \times 10^{-34}$ Js). Thus the angular momentum (L) of the orbiting electron is quantized. That is $L = nh/2\pi$.
3. Bohr's third postulate states that an electron might make a transition from one of its specified non-radiating orbits to another of lower energy. When it does so, a photon is emitted having energy equal to the energy difference between the initial and final states. The frequency(ν) of the emitted photon is then given by
$$h\nu = E_i - E_f$$
, where E_i and E_f are the energies of the initial and final states and $E_i > E_f$.
Or **Quantization of energy**.



Atomic structure: Bohr's model-shortcomings

1) uncertainty principle, 2) dual behaviour of particle



concepts of quantum mechanics

- **Quantum mechanics** is a science that deals with the study of the motions of the microscopic objects that have both observable wave like and particle-like properties.
- It specifies the laws of motion that these objects obey.
- *When quantum mechanics is applied to macroscopic objects (for which wave-like properties are insignificant) the results are the same as those from the classical mechanics.*

Atomic structure: Bohr's model-shortcomings

1) Uncertainty principle: Heisenberg

$$\Delta x \Delta p \geq \frac{h}{4\pi}$$

Planck's constant
 $6.62607015 \times 10^{-34} \text{ J-s}$

- Formulated by the German physicist and Nobel laureate Werner Heisenberg in 1932,
- The uncertainty principle states that we cannot know both the position and speed of a particle, such as a photon or electron, with perfect accuracy.

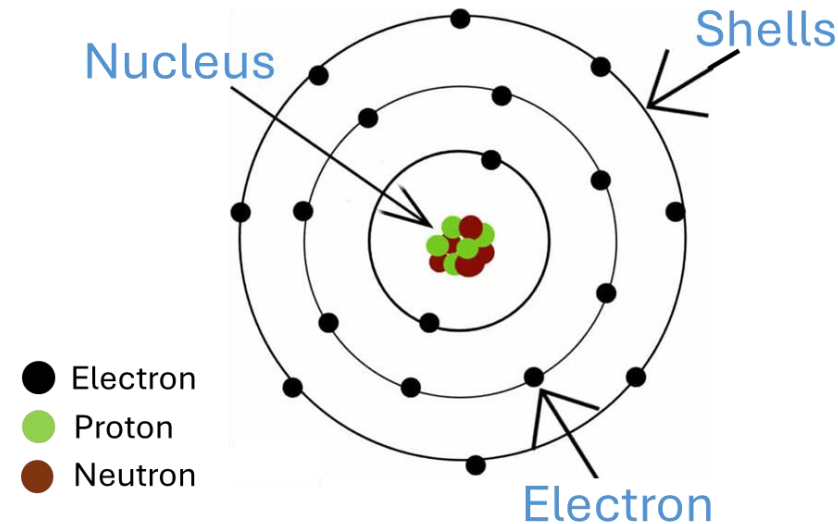
Atomic structure: Back to Bohr's model-shortcomings

Bohr's second postulate defines these stable orbits.

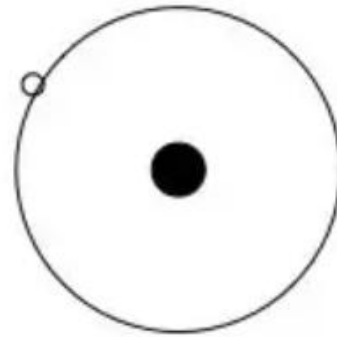
But according to Heisenberg's uncertainty principle

we cannot know both the position and speed of a particle, such as a photon or electron, with perfect accuracy.

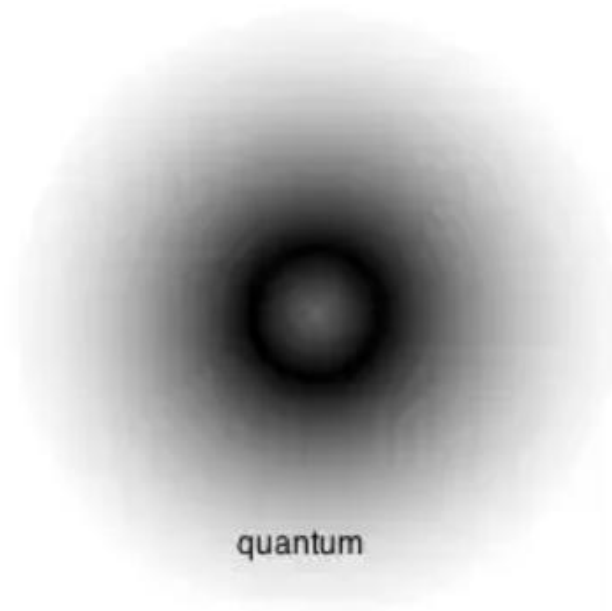
Model of the Atom



Atomic structure: classical and quantum picture



classical



quantum

Bohr: specify the path for electrons as orbits,
QM: **electron cloud around the nucleus**

Bohr: electron treated as static particle,
QM: **electron defined by a wavefunction**

Quantum Physics: Heisenberg's uncertainty principle

$$\Delta x \Delta p \geq \frac{h}{4\pi}; \Delta x \Delta p \geq \frac{\hbar}{2} \quad \hbar = \frac{h}{2\pi}$$

$$\Delta x \Delta v \geq \frac{h}{4\pi m}$$

This says that the uncertainty is small for massive objects, but becomes important for very light objects, such as electrons.

Large, massive objects don't show effects of quantum mechanics.

Quantum Physics: Heisenberg's uncertainty principle

$$\Delta x \Delta v \geq \frac{h}{4\pi m}$$

Wondering : is it only applicable to atomic electrons or a tennis ball also??

$$h = 6.626 \times 10^{-34} \text{ Js}$$

Mass of electron = 9.1×10^{-31} kg, uncertainty in speed = 5×10^6 m/s

Mass of tennis ball = 10 g, uncertainty in speed = 10 m/s

What is uncertainty in their positions?

Quantum Physics: Heisenberg's uncertainty principle

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Mass of tennis ball = 10 g, uncertainty in speed = 10 m/s

What is uncertainty in their positions?

Electron $\sim 1.1 \times 10^{-11}$ m ~ 0.01 nm

Tennis ball $\sim 5 \times 10^{-34}$ m

Quantum Physics: Heisenberg's uncertainty principle

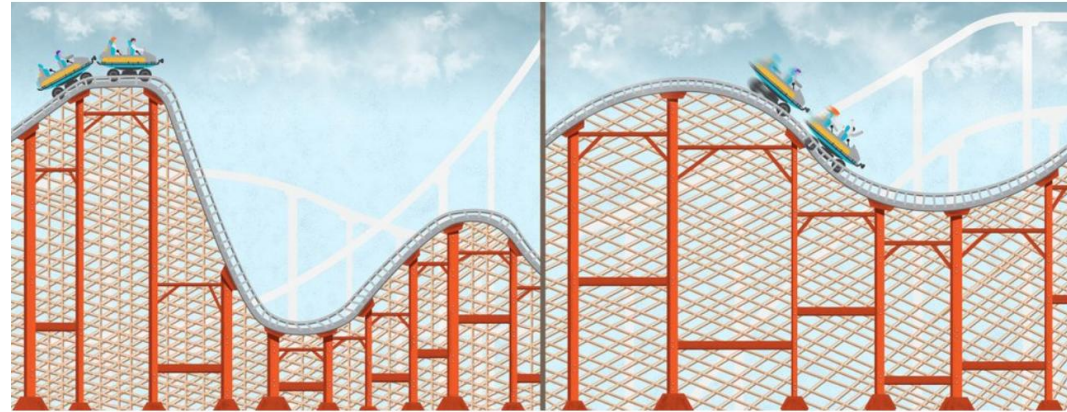
$$\Delta x \Delta v \geq \frac{h}{4\pi m}$$

- When concept of Quantum Mechanics (Uncertainty Principle) is applied to macroscopic objects, the results are undetectable,
OR
- we can safely say that when concept of Quantum Mechanics (Uncertainty Principle) is applied to macroscopic objects, the results are overlapping with Classical (or Newtonian Mechanics).

Quantum Physics: Heisenberg's uncertainty principle

$$\Delta x \Delta v \geq \frac{h}{4\pi m}$$

More formulations



Position but not speed

Speed but not position

$$\Delta E \Delta t \geq \frac{h}{4\pi}$$

one cannot measure the precise energy of a system in a finite amount of time

Quantum Physics: Heisenberg's uncertainty principle

"I, at any rate, am convinced
that He [God] does not throw
dice."

~Albert Einstein
on Quantum Mechanics

"Einstein, stop telling God
what to do."

~Niels Bohr on Einstein's
feeling about Quantum Physics



What have we learnt today?

- Bohr's atomic model
- Heisenberg's uncertainty principle-for the creation of quantum mechanics- awarded with 1932 Physics Nobel Prize
- Significance of Heisenberg's uncertainty principle

$$\Delta x \Delta v \geq \frac{h}{4\pi m}$$



Always be happy and grateful