The Quantum Mechanical Model of the Atom

Chapter 3.3
Quantum Mechanics

- **Quantum Mechanics** is the application of quantum theory to explain the properties of matter, particularly electrons in atoms.

- Three physicists paved the way to the quantum mechanical model of the atom:
  1. Erwin Schrödinger
  2. Louis de Broglie
  3. Werner Heisenberg
de Broglie and Schrödinger

- Had the idea that the electron, previously considered just a particle, has *wave* properties
- An electron bound to the nucleus of an atom resembles a standing wave (like the waves produced by the strings of a musical instrument)

- There are limitations on the allowed wavelengths of a standing wave
- Each end of the string is fixed so there is always a node at each end
- This means that there must be a whole number of half wavelengths in any of the allowed motions of the string
de Broglie and Schrodinger

- In their model, the electron is a circular standing wave around the nucleus.
- The circular standing wave consists of wavelengths that are multiples of whole numbers.
- Only certain circular orbits have a circumference into which a whole number of wavelengths can fit.

![Circular Standing Waves](image)

**Figure 3** The hydrogen electron visualized as a standing wave around the nucleus. In (a) and (b), the circumference of a particular circular orbit corresponds to a whole number of wavelengths. (c) Otherwise, destructive interference occurs. This model is consistent with the idea that only certain electron energies are allowed, because the atom is quantized. Although this idea encouraged scientists to use a wave theory, it does not mean that the electron travels in circular orbits around the nucleus.

The standing de Broglie waves set up in the first three Bohr orbits.
Schrodinger’s Wave Equation

- Schrodinger developed a mathematical equation, which could be used to calculate electron energy levels

\[-\frac{\hbar^2}{2m} \nabla^2 \Psi + \nabla \Psi = i\hbar \frac{\partial \Psi}{\partial t}\]

- Planck’s constant
- Called the ‘del-squared operator’, this quantity describes how the wavefunction, \( \Psi \), changes from one place to another
- A mathematical quantity called an ‘imaginary number’. It is equal to the square root of minus one
- The mass of the particle being described
- Describes the forces acting on the particle
- Describes how \( \Psi \) changes its shape with time
Werner Heisenberg

- **Heisenberg’s Uncertainty Principle** is the idea that it is impossible to know the exact position and speed of an electron at the same time.
  - The method used to determine the speed of an electron changes its position.
  - The method used to determine the position of an electron changes its speed.
- The best we can do is determine the probability of finding an electron in a specific location.
Orbitals and Probability Density

• An **orbital** is the region around the nucleus where the electron has a high probability of being found.

• Analogies: students in a school, a bee in a stadium.

• A **wave function** is a mathematical description of an orbital (it tells us the mathematical probability of finding an electron in a certain region of space).

• Note: Quantum mechanics does not describe *how* an electron moves.
Electron Probability Density

• Also called Electron Probability Distribution
• Is a graph that indicates regions around the nucleus with the greatest probability of finding an electron
• It is derived from wave equations
• It is used to determine the shapes of orbitals
Electron Probability Density

- Used to determine the shape of an orbital

Most orbitals are spherical

Some orbitals are dumbbell shaped

An atom consists of many overlapping orbitals
# Orbits vs. Orbitals

Orbitals versus Orbits

The table below outlines the main differences between orbitals and orbits.

<table>
<thead>
<tr>
<th>Orbitals</th>
<th>Orbits</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 electrons</td>
<td>$2n^2$ electrons</td>
</tr>
<tr>
<td>three dimensions</td>
<td>two dimensions</td>
</tr>
<tr>
<td>distance from nucleus varies</td>
<td>distance from nucleus is fixed</td>
</tr>
<tr>
<td>no set path</td>
<td>path is elliptical or circular</td>
</tr>
</tbody>
</table>

*Note: The table provides a comparison between orbitals and orbits, highlighting the key differences in terms of electron count, dimensions, and the nature of their motion.*
HOMEWORK

Required Reading:

p. 148-152
(remember to supplement your notes!)

Questions:

p. 152 #1-8, 11