# The Quantum Model of the Atom

## *Electrons as Waves*

The investigations into the photoelectric effect and hydrogen's line-emission spectrum revealed that light could behave as both a wave and a particle. Louis de Broglie pointed out that in many ways the behavior of electrons in Bohr's quantized orbits was similar to the known behavior of waves. He suggested that electrons be considered waves confined to the space around an atomic nucleus. It followed that the electron waves could exist only at specific frequencies. According to the relationship $E=hv$, these frequencies corresponded to specific energies—the quantized energies of Bohr's orbits.

Other Aspects of de Broglie's hypothesis that electrons have wavelike properties was soon confirmed by experiments. Investigators demonstrated that electrons, like light waves, can be bent, or diffracted. *Diffraction* refers to the bending of a wave as it passes by the edge of an object or through a small opening. These experiments and other investigations also showed that electron beams, like waves, can interfere with each other. *Interference* occurs when waves overlap, which results in a reduction of energy in some areas and an increase of energy in others.

## *The Heisenberg Uncertainty Principle*

In 1927, Werner Heisenberg's idea involved the detection of electrons. Electrons are detected by their interaction with photons. Because photons have about the same energy as electrons, any attempt to locate a specific electron with a photon knocks the electron off its course. As a result, there is always a basic uncertainty in trying to locate an electron (or any other particle). *The* **Heisenberg uncertainty principle** *states that it is impossible to determine simultaneously both the position and velocity of an electron or any other particle.*



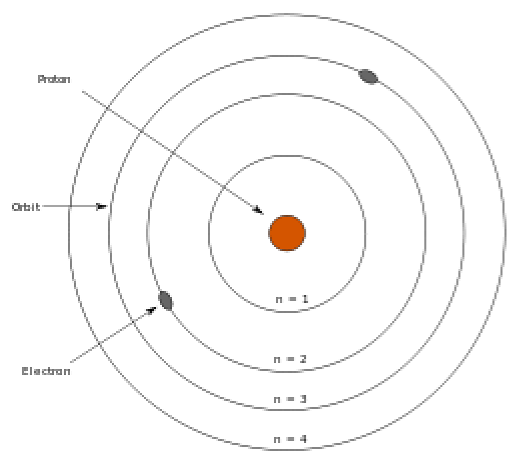
## *The SchrÖdinger Wave Equation*

In 1926, Erwin Schrödinger used the hypothesis that electrons have a dual wave-particle nature to develop an equation that treated electrons in atoms as waves. Quantization of electron energies was a natural outcome of Schrödinger's equation. Only waves of specific energies, and therefore frequencies, provided solutions to the equation. Together with the Heisenberg uncertainty principle, the Schrödinger wave equation laid the foundation for modern quantum theory. **Quantum theory** *describes mathematically the wave properties of electrons and other very small particles*.

Solutions to the wave equation are known as wave functions. Early developers of quantum theory determined that wave functions give only the probability of finding an electron at a given place around the nucleus. Electrons exist in certain regions called orbitals. *An* **orbital** *is a three-dimensional region around the nucleus that indicates the probable location of an electron.*

## *Atomic Orbitals and Quantum Numbers*

In order to completely describe orbitals, scientists use quantum numbers. Quantum numbers specify the properties of atomic orbitals and the properties of electrons in orbitals. The first three quantum numbers result from solutions to the Schrödinger equation. They indicate the main energy level, the shape, and the orientation of an orbital. The fourth, the spin quantum number describes a fundamental state of the electron that occupies the orbital.




*The main energy levels of an atom are represented by the principal number, n.*

### *Principal Quantum Number*

*The* **principal quantum number**, *symbolized by n, indicates the main energy level occupied by the electron*. Values of *n* are positive integers