Chapter 32

The Atom and the Quantum

Physics in the Modern Era

Milestones:

- Electron discovered in 1898 by J. J. Thompson
- Nucleus discovered in 1911 by E. Rutherford
- Neutron discovered in 1932 by J. Chadwick

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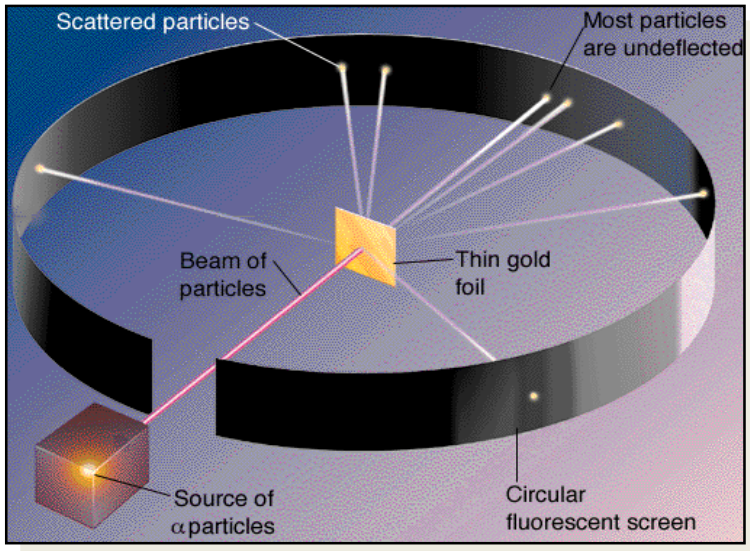
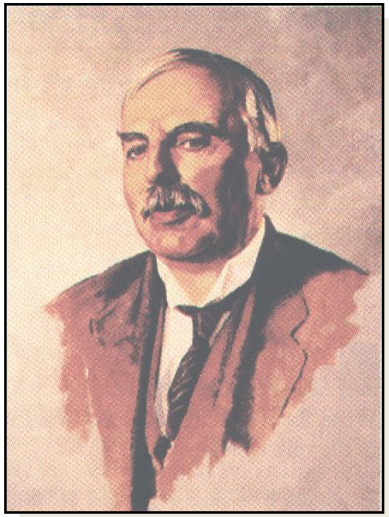
Atomic Nucleus Discovered

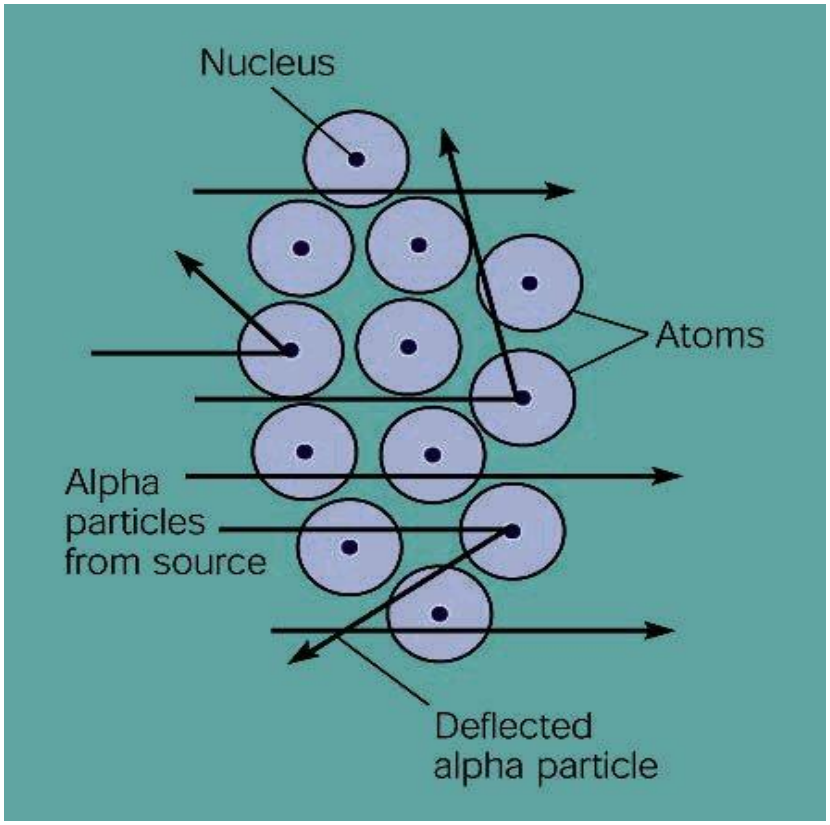
In the "gold foil experiment," Rutherford aimed alpha radiation through a thin gold foil. The scattering pattern showed that most went straight through while a few were deflected at very high angles (contrary the pattern predicted by J. J. Thompson's "plum pudding modal" of the atom.





More on Rutherford's Discovery

Based on the particles deflection pattern, Rutherford calculated the fraction of the atomic volume occupied by the positive nuclei, that is 1 part in 10^{14}. The mass is so dense that a nucleus the size of a pea would have mass greater that 250 million tons. this led to the modern view of the atom.

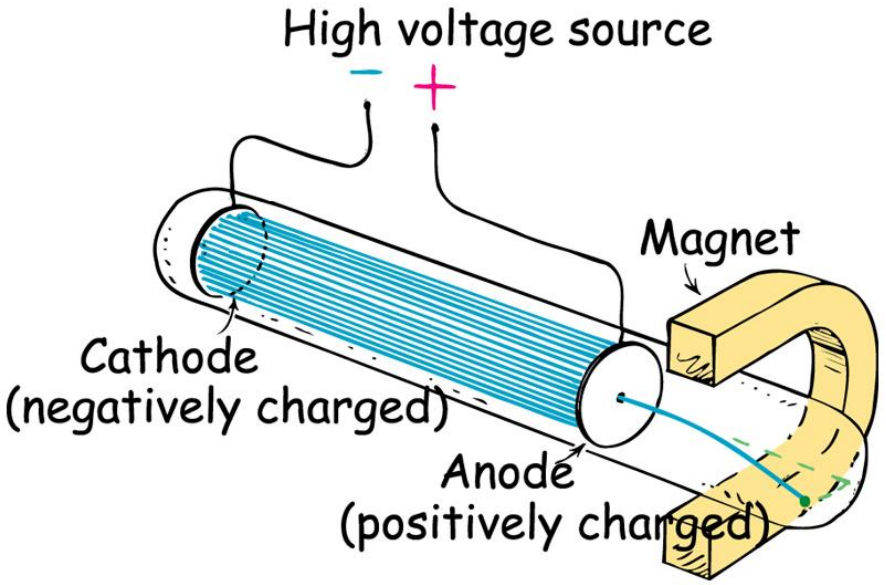


Electrons Discovered

A cathode ray is a beam of electrons that moves between metal plates in an evacuated tube from a negative to a positive terminal.

The electron beam is seen as a green beam.

These rays can be deflected by a magnet.



Electrons Discovered

In 1897 **JJ Thompson** placed a positively charged plate on one side of the tube and a negatively charged plate on the other side of the tube.

The beam was deflected away from the negative plate toward the positive plate.

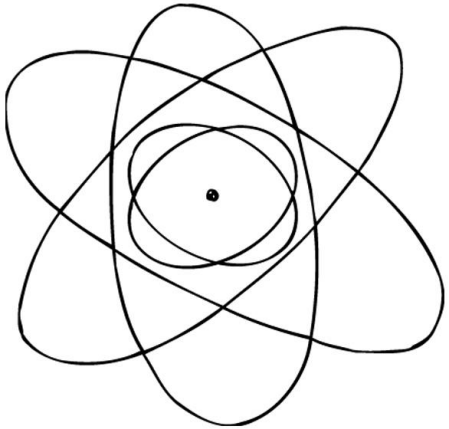
Thompson realized that the particles that made up the beam must be negatively charged, since like charges repel and opposite charges attract.

By balancing the deflections made by the magnet with that made by the electrical field, Thompson was able to calculate the **ratio of the charge to mass of an electron as 1.7584 X 10^{11}** coulomb/kilogram.

These particles later became known as *electrons*.

The Bohr Model of the Atom

- Electrons “orbit” the nucleus in groups or clouds called “shells.”



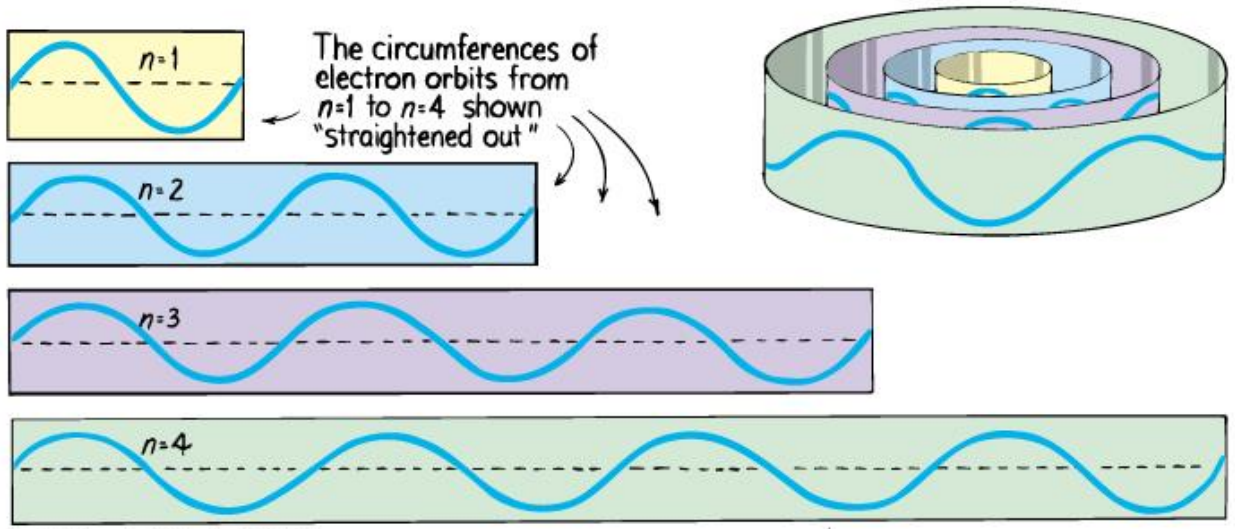
Why are atoms stable?

- Wave nature of the electron provides the answer: the electron “orbits” form standing waves only at certain allowed energies.
- What is “waving?” Waves of probability! Where the clouds are “thick” is where the electron is likely to be found.

Electron Waves

Recall in the last chapter that particles the microscopic realm, particle has measureable wave-like properties: reflection, refraction, diffraction, interference, etc.

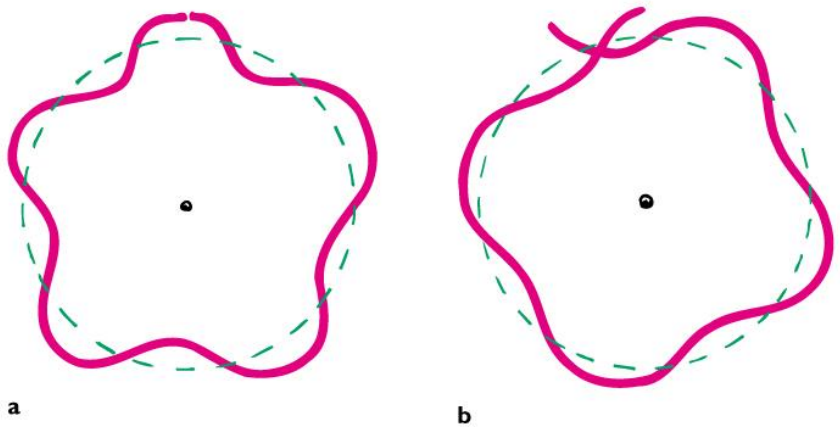
It is this behavior of these "matter waves" that explains the discrete energy levels as observed in the atomic spectra.



Electron Waves and "Orbits"

The electron waves set up standing waves around the nucleus with the innermost "orbit" is wavelength, the 2nd is 2 wavelengths, and so on.

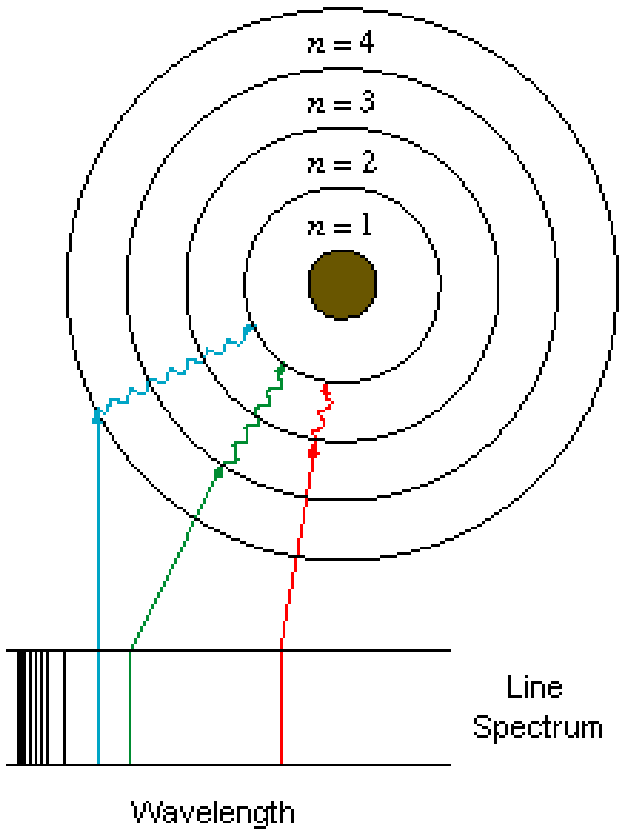
Only "orbits" that form a standing wave are possible. Otherwise the electron wave interferes with itself destructively (as shown at right below).



Atomic Spectra Explained

Since the electron waves have discrete circumferences when the standing wave condition is met, it follows that the electron orbits (and energies) are also discrete. Electrons can only take certain "allowed" energies.

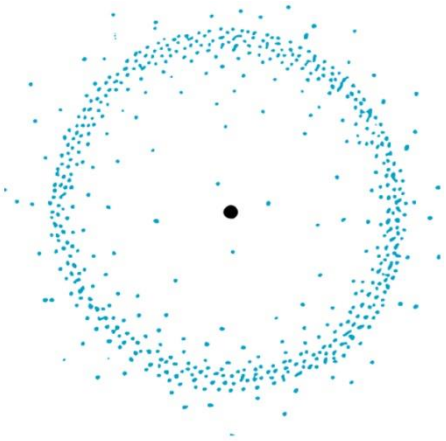
This accounts for the discrete spectral distributions observed in the atomic spectra.

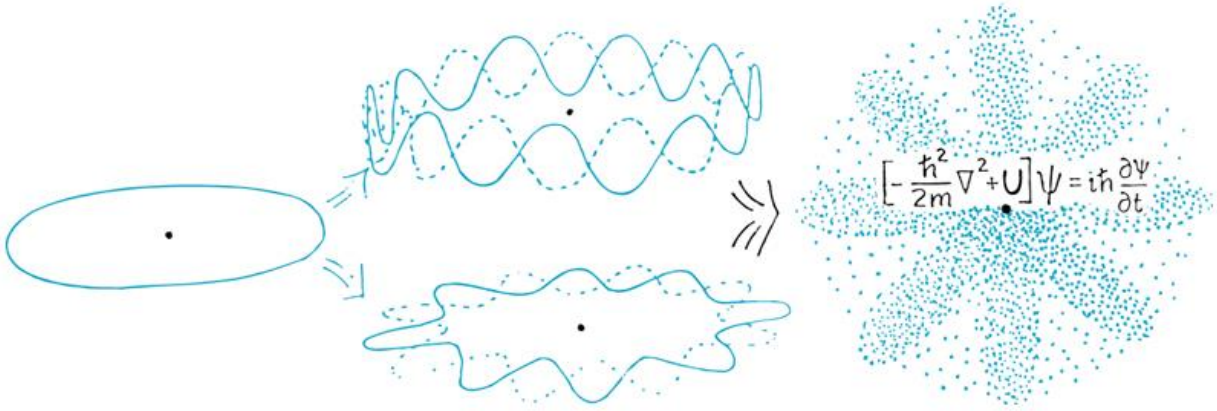


Quantum Mechanics

The modern view of the electron "orbits" is that the discrete energies of the electron levels form "clouds of probability" around the nucleus. Where the clouds are "thick" there is a high probability of finding the electron.

These probabilities are calculated by solving the Schrodinger equation. This gives a purely mathematical description.





The Correspondence Principle

It is clear that the familiar Newton's laws break down in the subatomic realm. The new theory of quantum mechanics (developed in the mid 1920's), explains the observed microscopic behaviors. Still, if any new theory is to be valid, it must be able to account for the verified results of the old theory where the old theory was valid.

When applied to macroscopic systems, quantum mechanics does indeed smoothly blend into the classical theory of Newton.