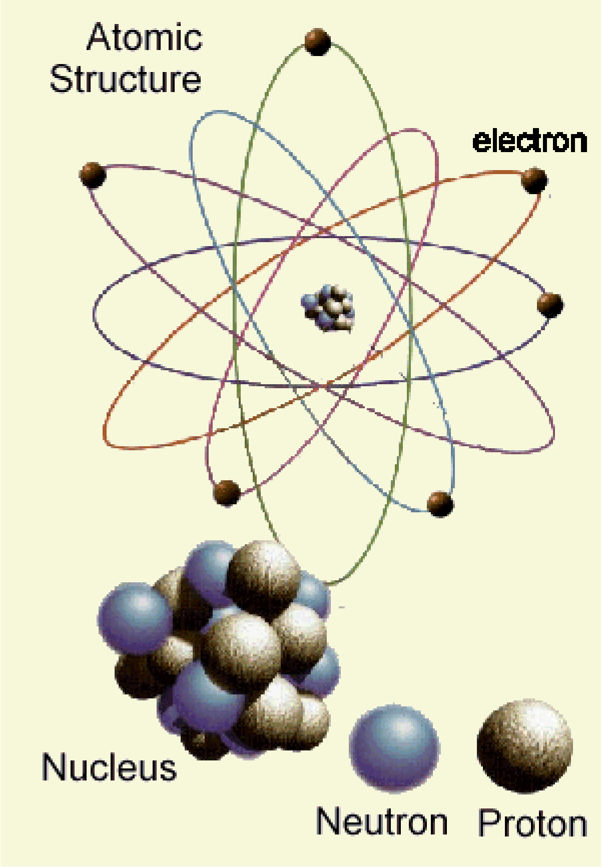
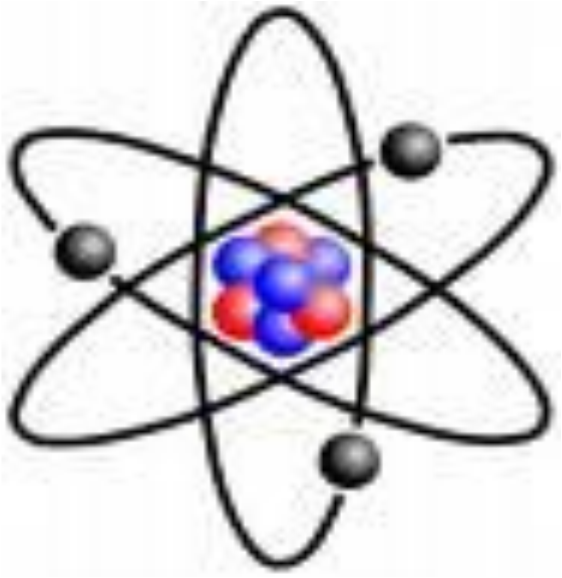
Chapter 5: Electrons in Atoms



Models of the Atom

- Rutherford used existing ideas about the atom and proposed an atomic model in which the electrons move around the nucleus, like the planets move around the sun.



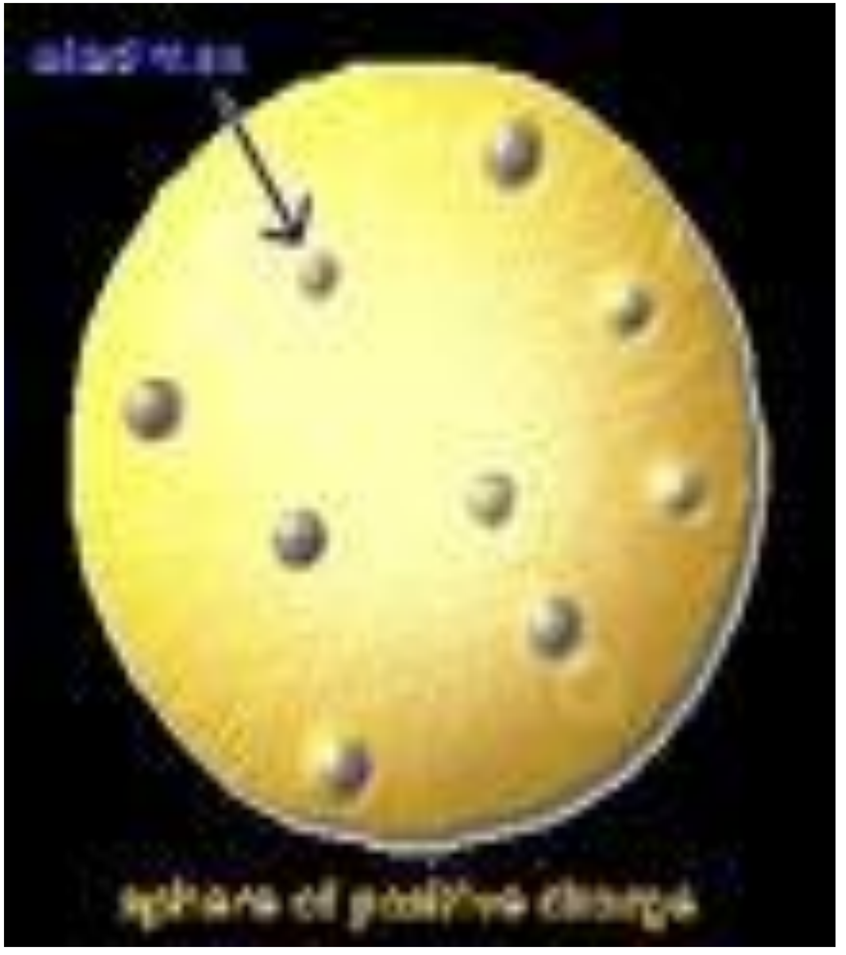
- Rutherford’s atomic model could not explain the chemical properties of elements.
  - Rutherford’s model fails to explain why objects change color when heated.

Models of The Atom

1863- John Dalton pictures atoms as tiny, indestructible particles, with no internal structure.

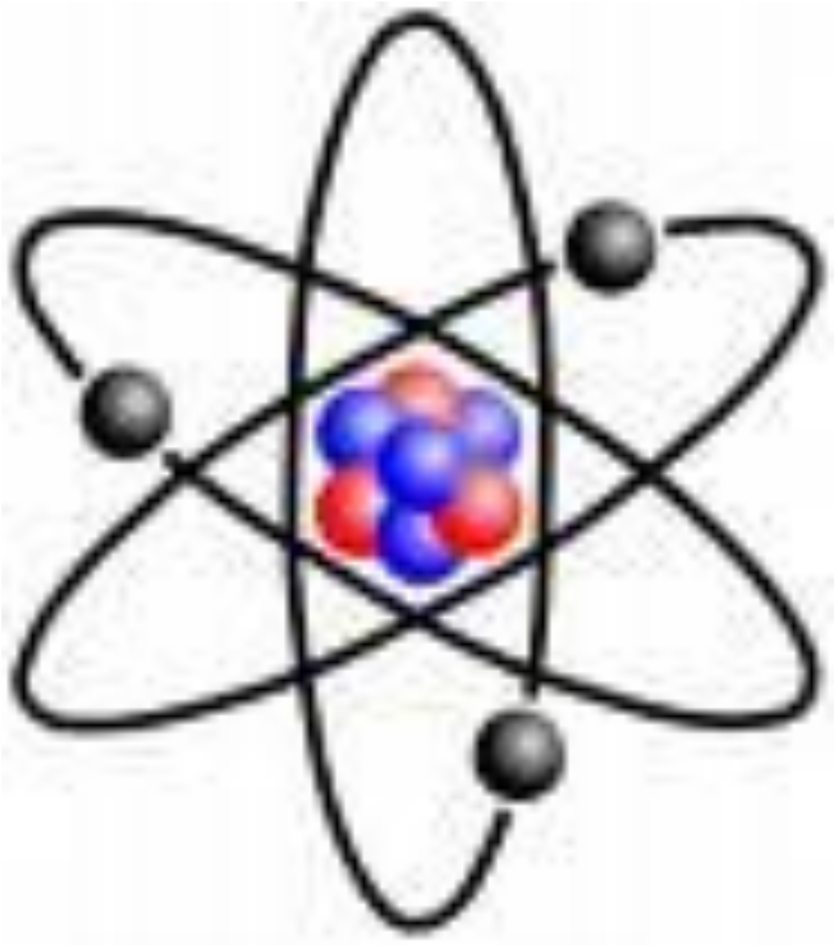
Models of the Atom

- 1897- J.J. Thomson, a British scientist, discovers the electron. The later leads to his “Plum Pudding” model. He pictures electrons embedded in a sphere of positive electrical charge.



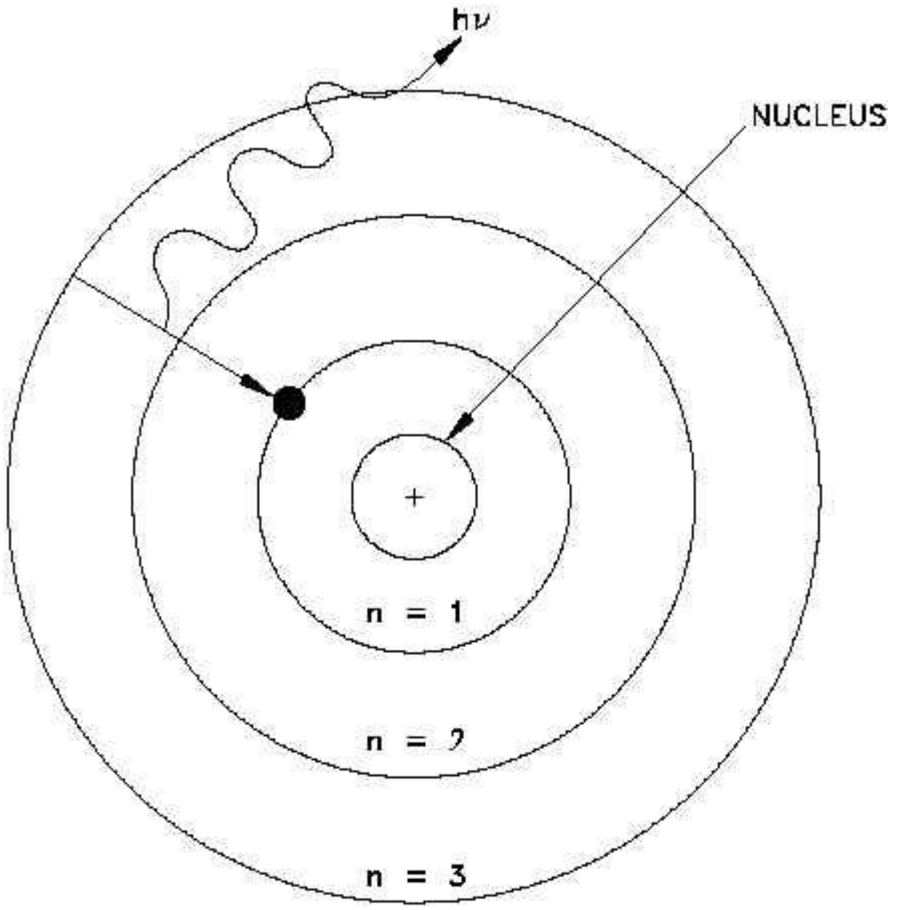
Models Of the Atom

- 1911- Ernest Rutherford finds that an atom has a small, dense, positively charged nucleus. Electrons move around the nucleus.



Models of the Atom

- 1913- Neils Bohr's model, the electron moves in a circular orbit at fixed distances from the nucleus.

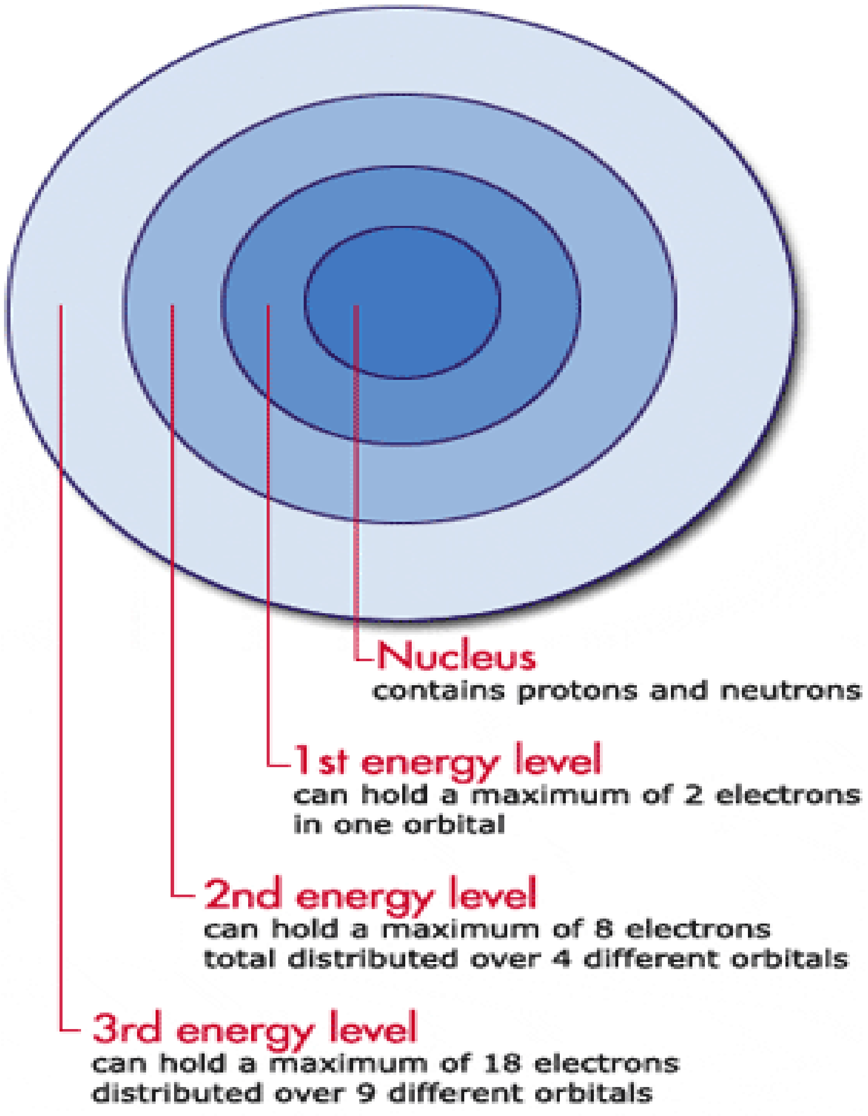


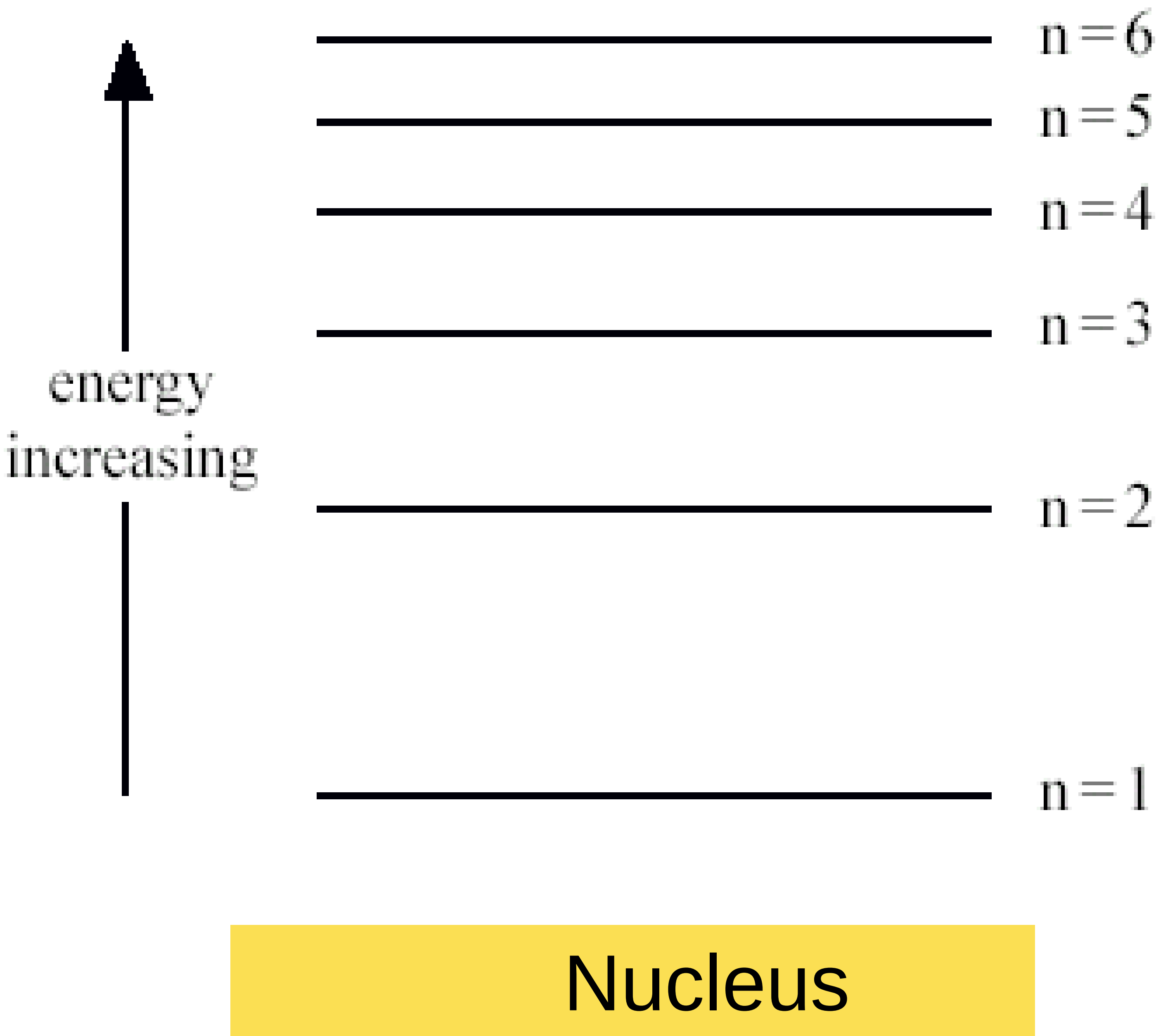
The Bohr Model

- **Bohr proposed that an electron is found only in specific circular paths, or orbits, around the nucleus.**
- **Each orbit has a fixed energy. These fixed energies an electron can have are called energy levels.**

- These ladder steps are somewhat like energy levels.
- The higher an electron is on the energy ladder, the farther it is from the nucleus.
- quantum of energy is the amount of energy required to move an electron from one energy level to another energy level.

- To move from one energy level to another an electron must gain or lose just the right amount of energy.
- The higher an electron is on the energy ladder, the farther from the nucleus.



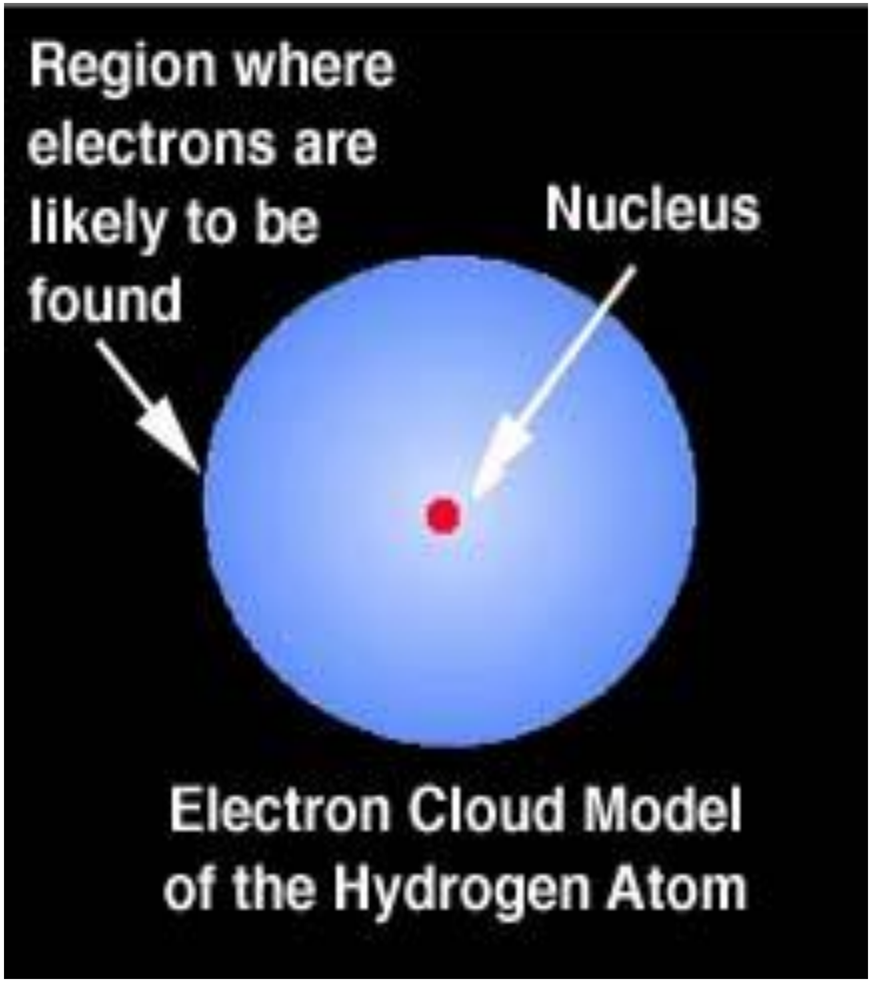

n = 6
n = 5
n = 4
n = 3
n = 2
n = 1
energy
increasing
Nucleus

The Bohr Model

- The Bohr model establishes the concept of definite electron energy levels within atoms. But Bohr's model was rather simplistic and as scientists made more discoveries about more complex atoms, Bohr's model was modified and eventually was replaced by more sophisticated models.

Models Of the Atom

- 1926- Erwin Schrodinger develops mathematical equations to describe the motion of electrons in atoms. His work leads to the electron cloud model.



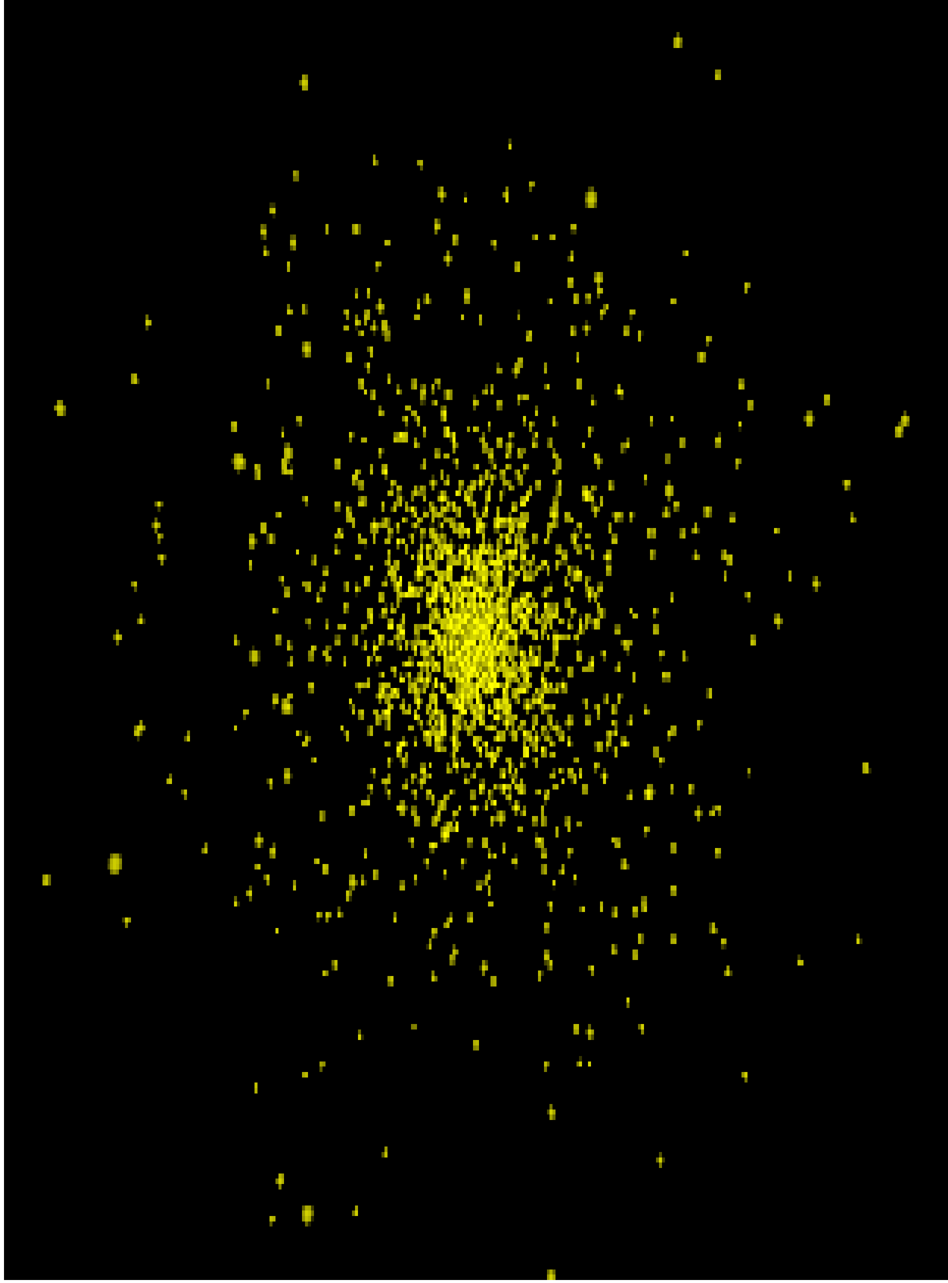
The Quantum Mechanical Model

- The modern description of the electrons in atoms, the Quantum Mechanical Model, comes from the mathematical solutions to the Schrodinger equation.
- Like the Bohr model, the quantum mechanical model of the atom restricts the energy of electrons to certain values.
- Unlike the Bohr model, however, the QMM does not involve an exact path the electron takes around the nucleus.

Key Concept!!!

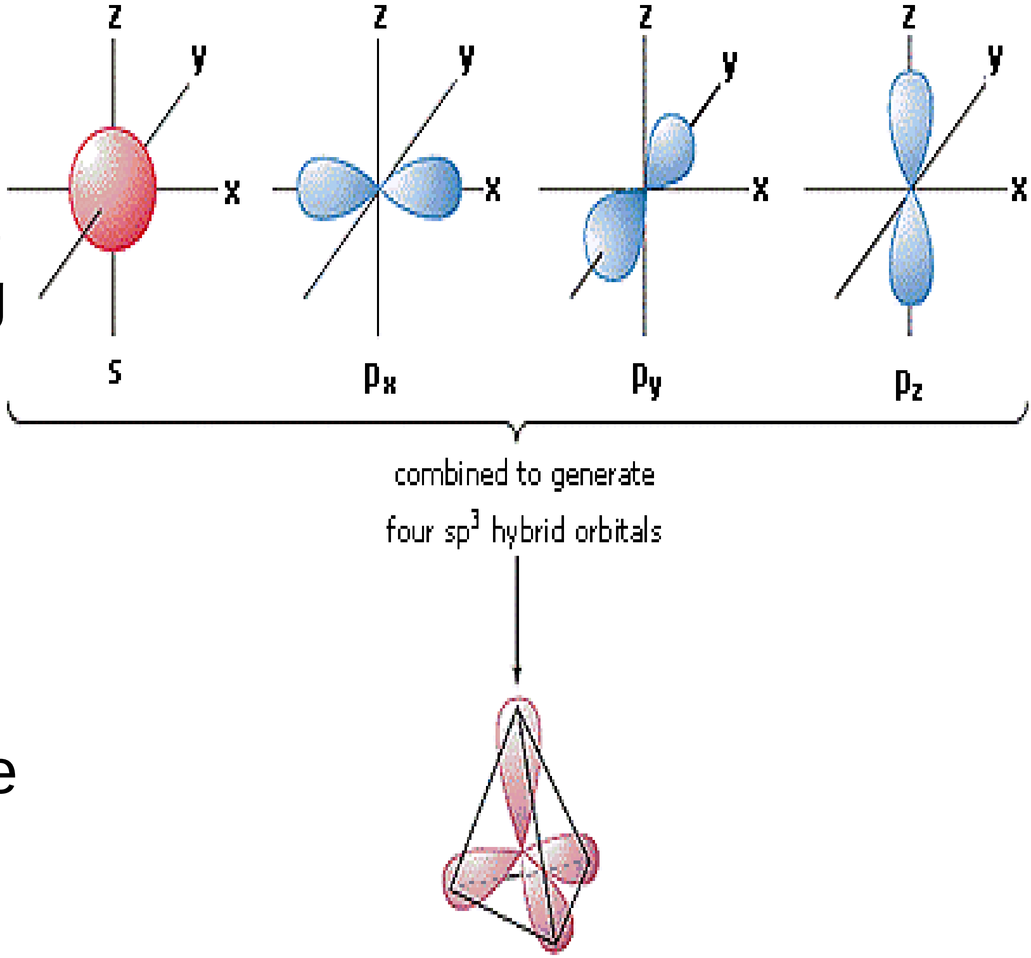
- The Quantum Mechanical model determines the allowed energies an electron can have and how likely it is to find the electron in various locations around the nucleus.

- Here is a quantum mechanical picture of an Hydrogen atom. The nucleus is not shown, but is located at the center of the picture.
- Here are some things to notice:
- Like the heads you can see where the electron is most likely to be: **near the nucleus** (the center of the picture).
- You can't tell exactly where the electron is, just where it is most likely to be.
- The individual dots are not electrons. They are meant to be used in the context of how dense, or heavy an area of dots appears.
- The more crowded (or heavier packed) the dots are in a particular region, the better chance you have to finding your electron there.



Atomic Orbitals

- An atomic orbital is often thought of as a region of space in which there is a high probability of finding an electron.
- Each energy level corresponds to an orbital of a different shape, which describes where the electron is likely to be found.



- Here is a cool website that shows the different orbitals!!!

The Orbitron: a gallery of atomic orbitals and molecular orbitals

Atomic Orbitals Cont…

- The numbers and kinds of atomic orbitals depend on the energy sublevel.
- The lowest principal energy level (n=1) has only one sublevel, called 1s.
- The second level (n=2) has two sublevels, 2s and 2p. Thus, the second energy level has four orbitals: 2s, $2p_x$,$2p_y$,$2p_z$.
- The third level (n=3) has three sublevels, 3s,3p and 3d. Thus the third energy level has nine orbitals: one 3s, three 3p, and five 3d.
- The fourth level (n=4) has four sublevels, 4s,4p,4d, and 4f. Thus the fourth energy level has 16 orbitals: one 4s, three 4p, five 4d, and seven 4f orbitals.

Maximum # of Electrons

Energy level n	Max. # of electrons
1	2
2	8
3	18
4	32

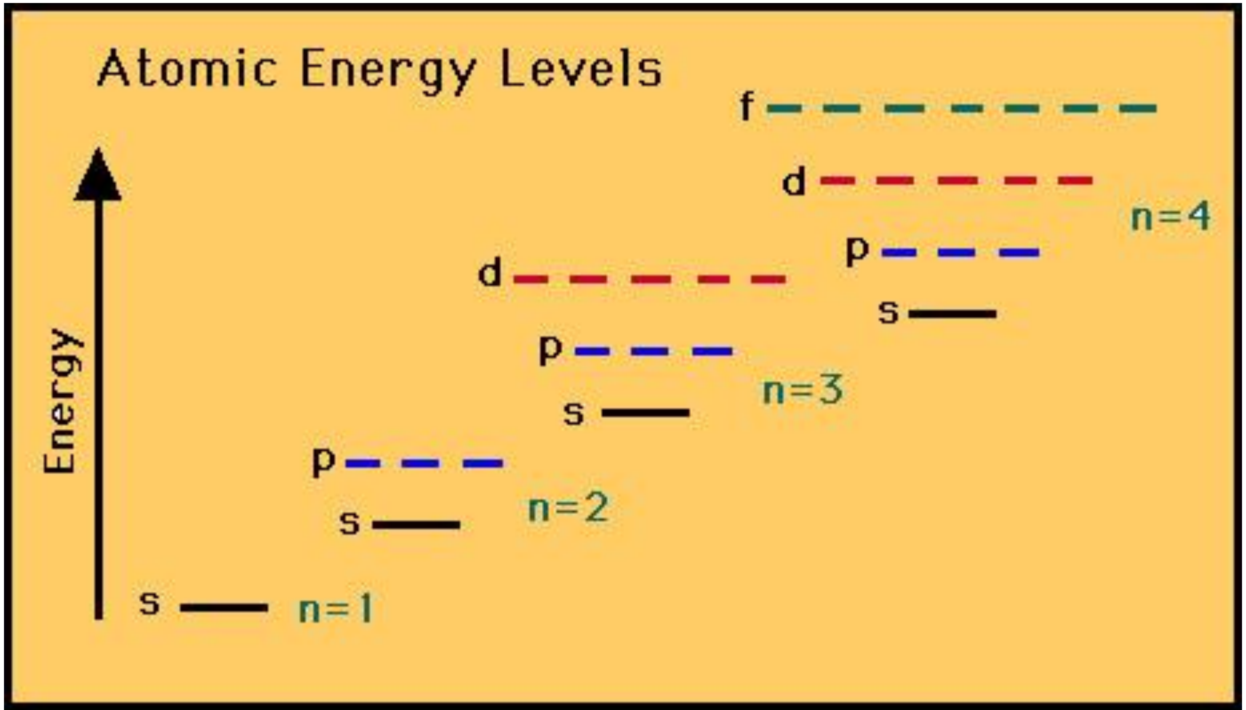
5.2 Electron Arrangement in Atoms

- The ways in which electrons are arranged in various orbitals around the nuclei of atoms are called electron configurations.

- Three Rules- the Aufbau Principle, the Pauli exclusion principle, and Hund's rule- tell you how to find the electron configurations of atoms.

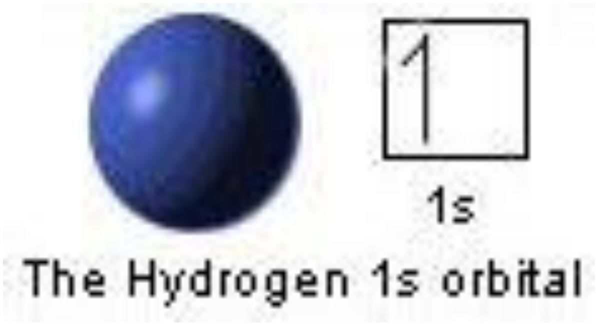
Aufbau Principle

- Electrons occupy the orbitals of lowest energy first.



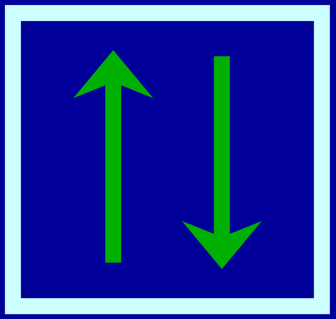
Pauli Exclusion Principle

- An atomic orbital may describe at most two electrons.
  - For example, either one or two electrons can occupy an s or p orbital. To occupy the same orbital, two electrons must have opposite spins; that is, the electron spins must be paired.



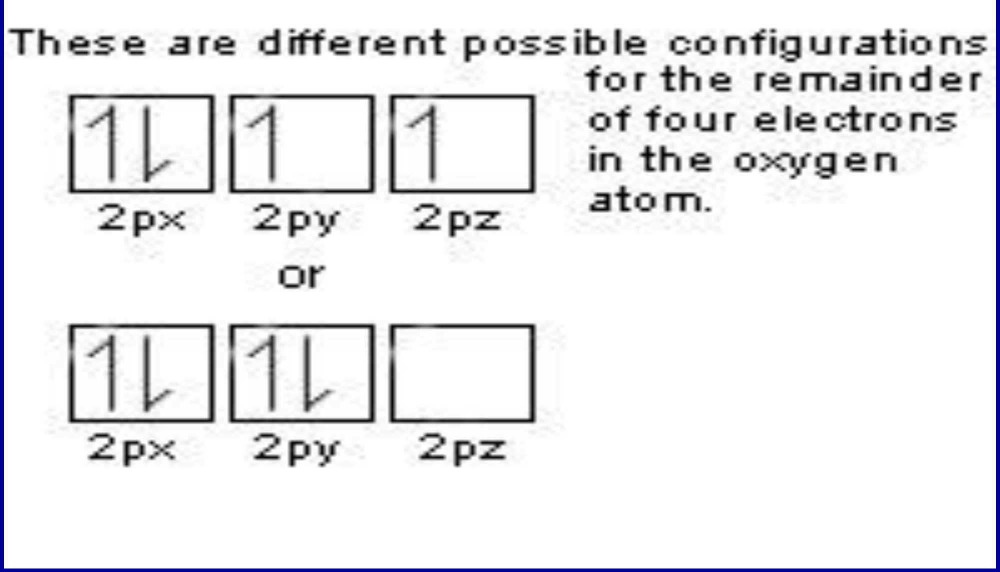
A. General Rules

- **Pauli Exclusion Principle**
  - Each orbital can hold TWO electrons with opposite spins.



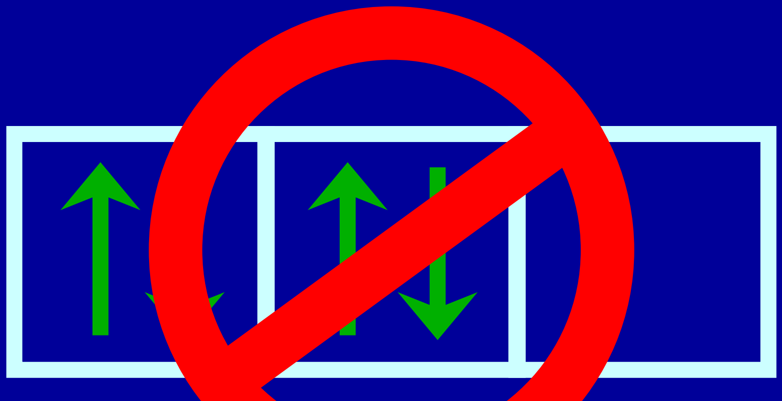
Hund's Rule

- Electrons occupy orbitals of the same energy in a way that makes the number of electrons with the same spin direction as large as possible.

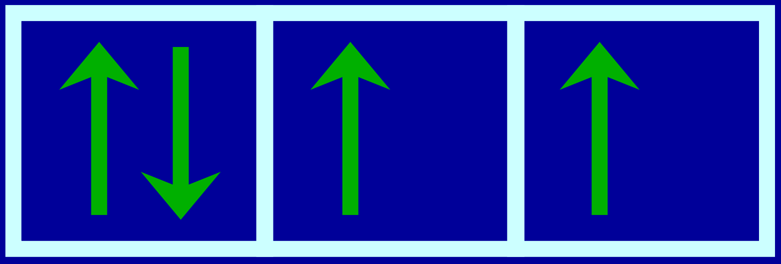


A. General Rules

- **Hund's Rule**
  - Within a sublevel, place one e^- per orbital before pairing them.
  - "Empty Bus Seat Rule"



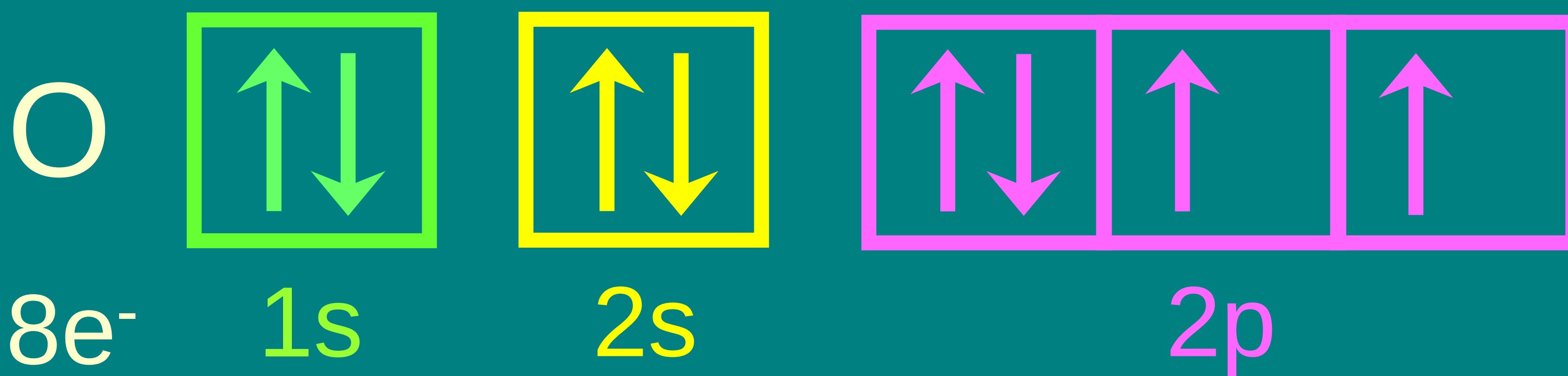
WRONG



RIGHT

B. Notation

- **Orbital Diagram**



- **Electron Configuration**

$$\mathbf{1s^2\ 2s^2\ 2p^4}$$

B. Notation

- **Longhand Configuration**

S 16e^- $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

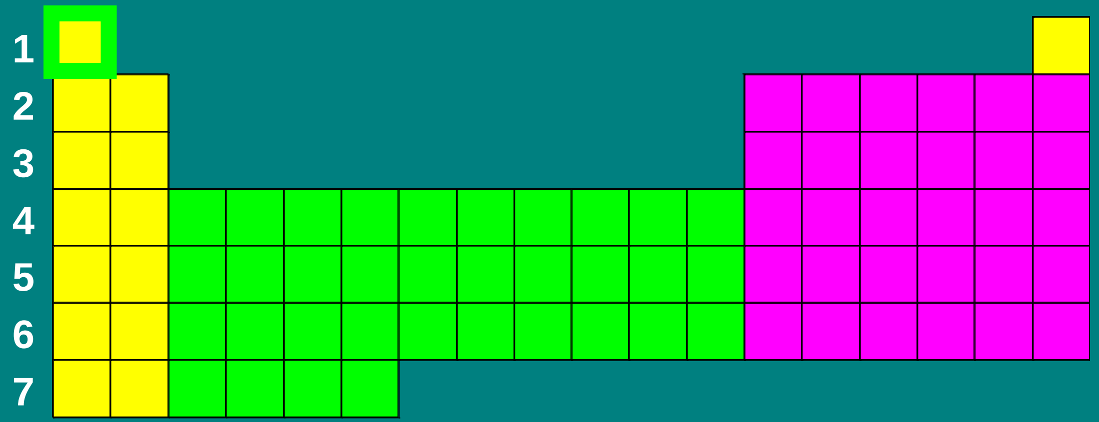
Core Electrons — Valence Electrons

- **Shorthand Configuration**

S 16e^- [Ne] $3s^2\ 3p^4$

C. Periodic Patterns

- **Example -** Hydrogen



$$1s^1$$

1st column of s-block

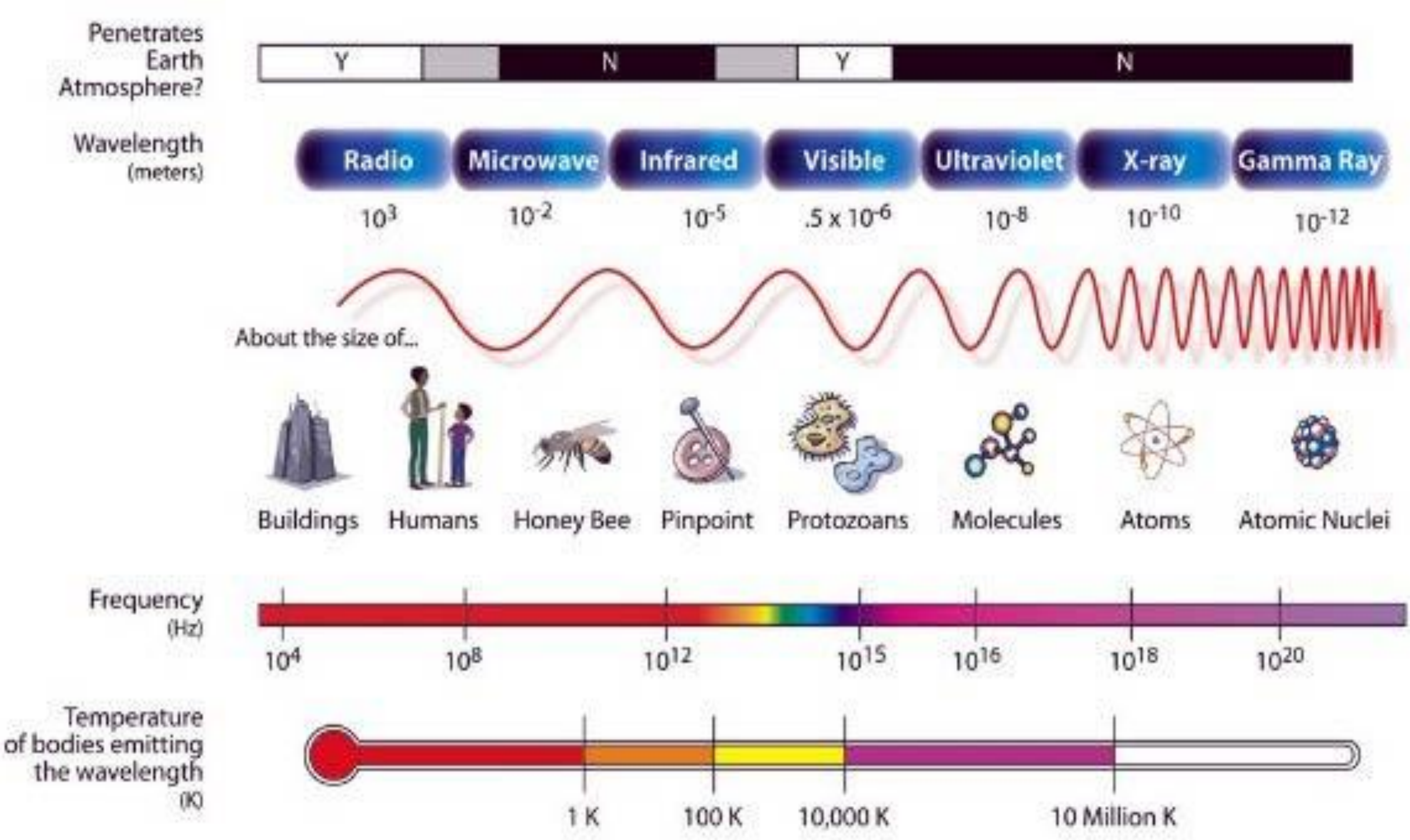
1st Period

s-block

Practice, Practice, Practice!!!

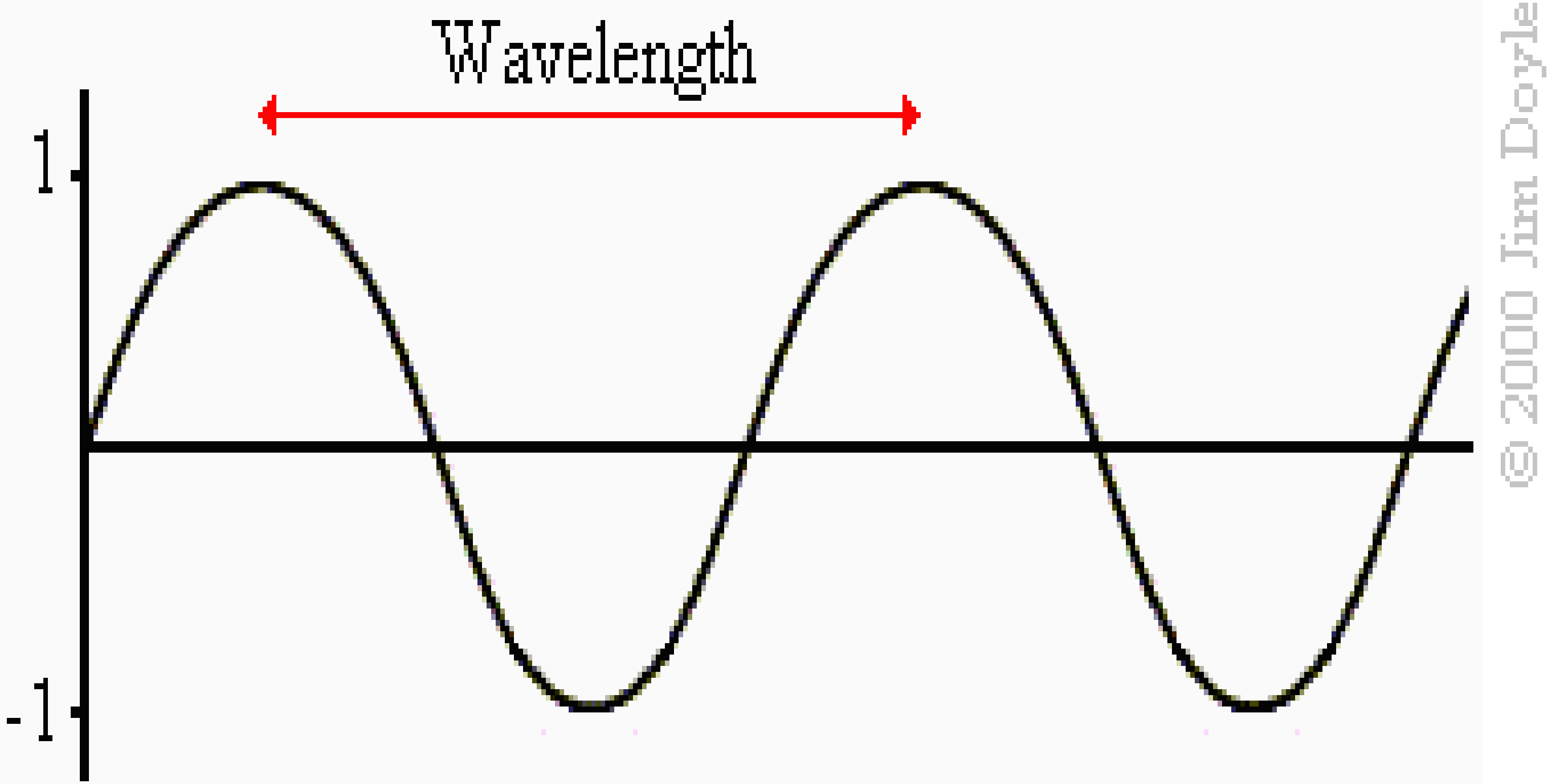
- Write the electron configurations for each atom.
- **Carbon**
- **Argon**
- **Nickel**

5.3 Physics and the QMM



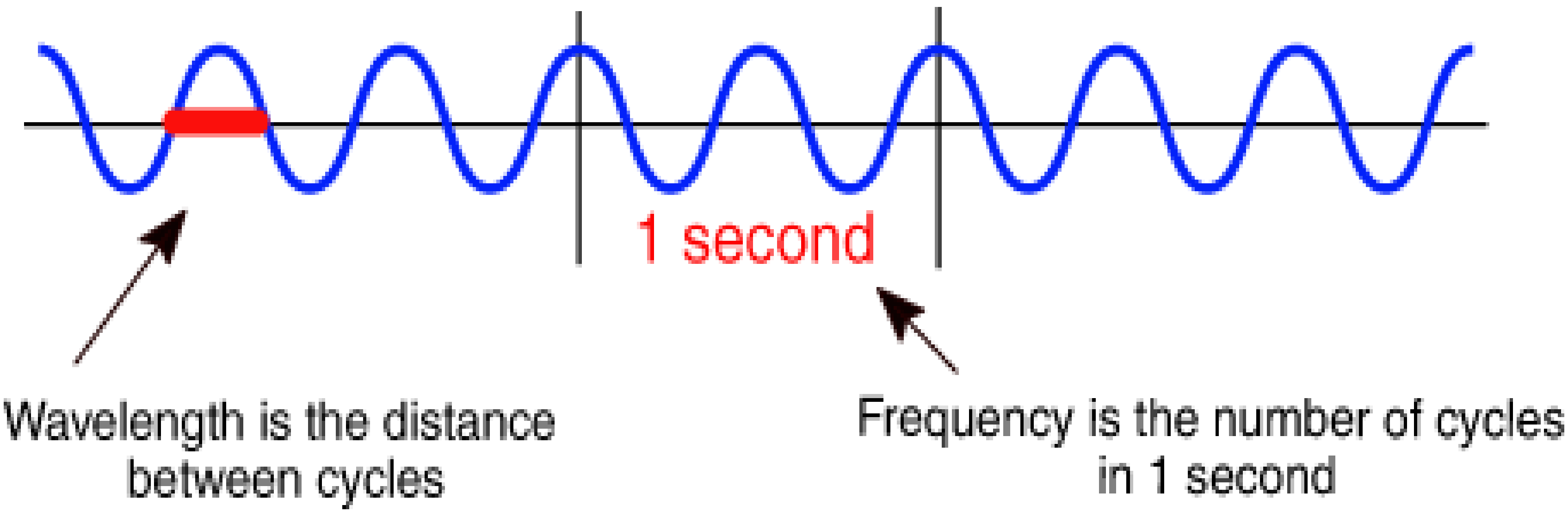
Light

- The Quantum mechanical model grew out of the study of light.
- Isaac Newton tried to explain what was known about the behavior of light by assuming that light consists of particles.
- By the year 1900, there was enough evidence to say that light consists of waves.

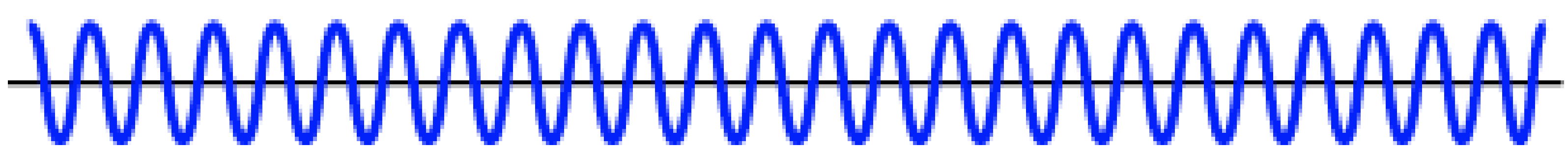


The wavelength of a wave

LOWER FREQUENCY = LONGER WAVELENGTH



HIGHER FREQUENCY = SHORTER WAVELENGTH



The wavelength of light are inversely proportional to each other.

$$\text{frequency} = \frac{c}{\lambda}$$

$$\lambda = \frac{c}{\text{frequency}}$$

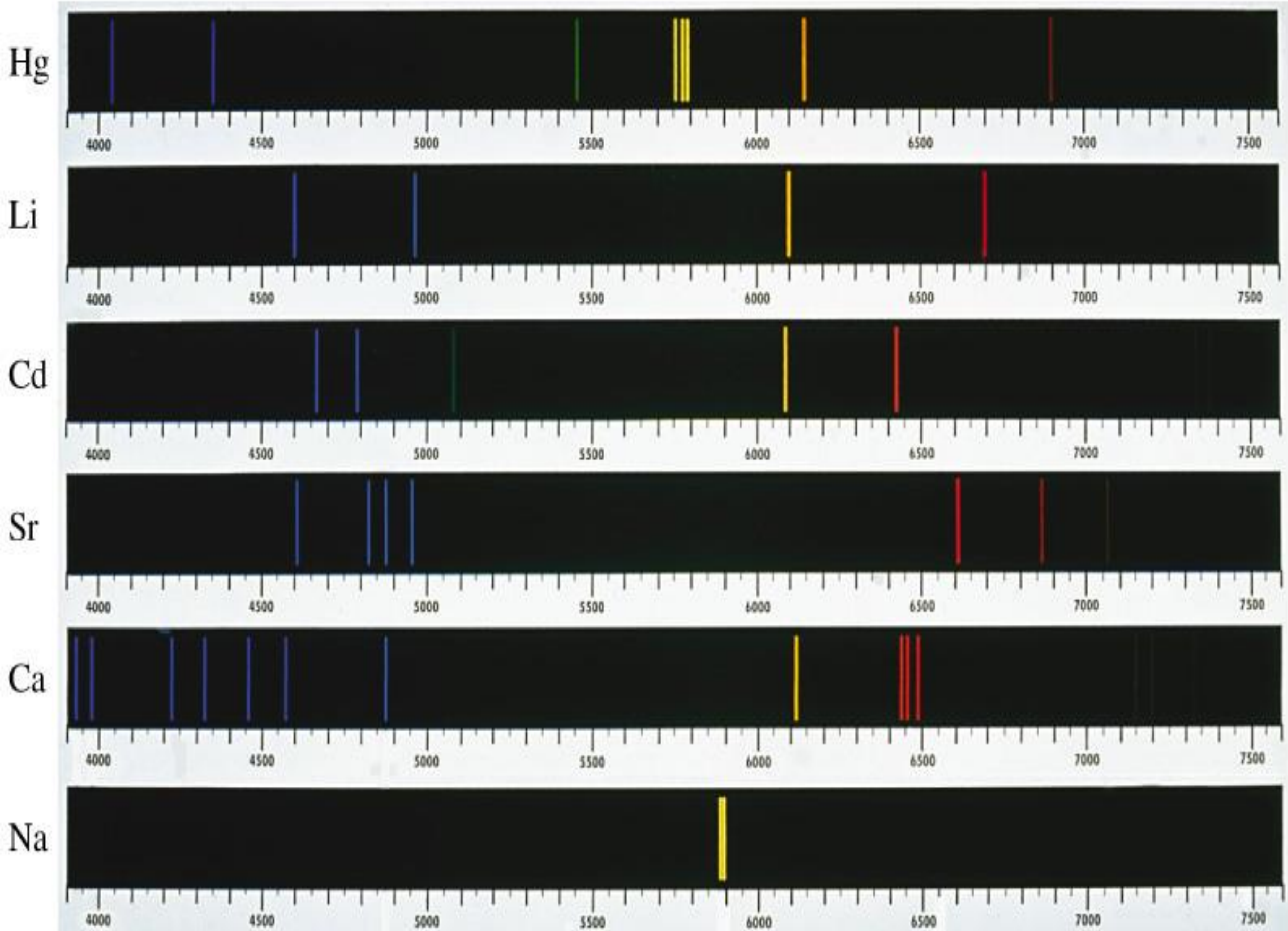
Calculating the wavelength of light

- Practice Problems on Page 140.

- When atoms absorb energy, electrons move into higher energy levels, and these electrons lose energy by emitting light when they return to lower energy levels.

Atomic Emission Spectrum

- Each specific frequency of visible light emitted corresponds to a particular color. When the light passes through a prism, the frequencies of light emitted by an element separate into discrete lines to give the atomic emission spectrum of the element.
- The emission spectrum of each element is like a person's fingerprint.


Hg
Li
Cd
Sr
Ca
Na
4000
4500
5000
5500
6000
6500
7000
7500

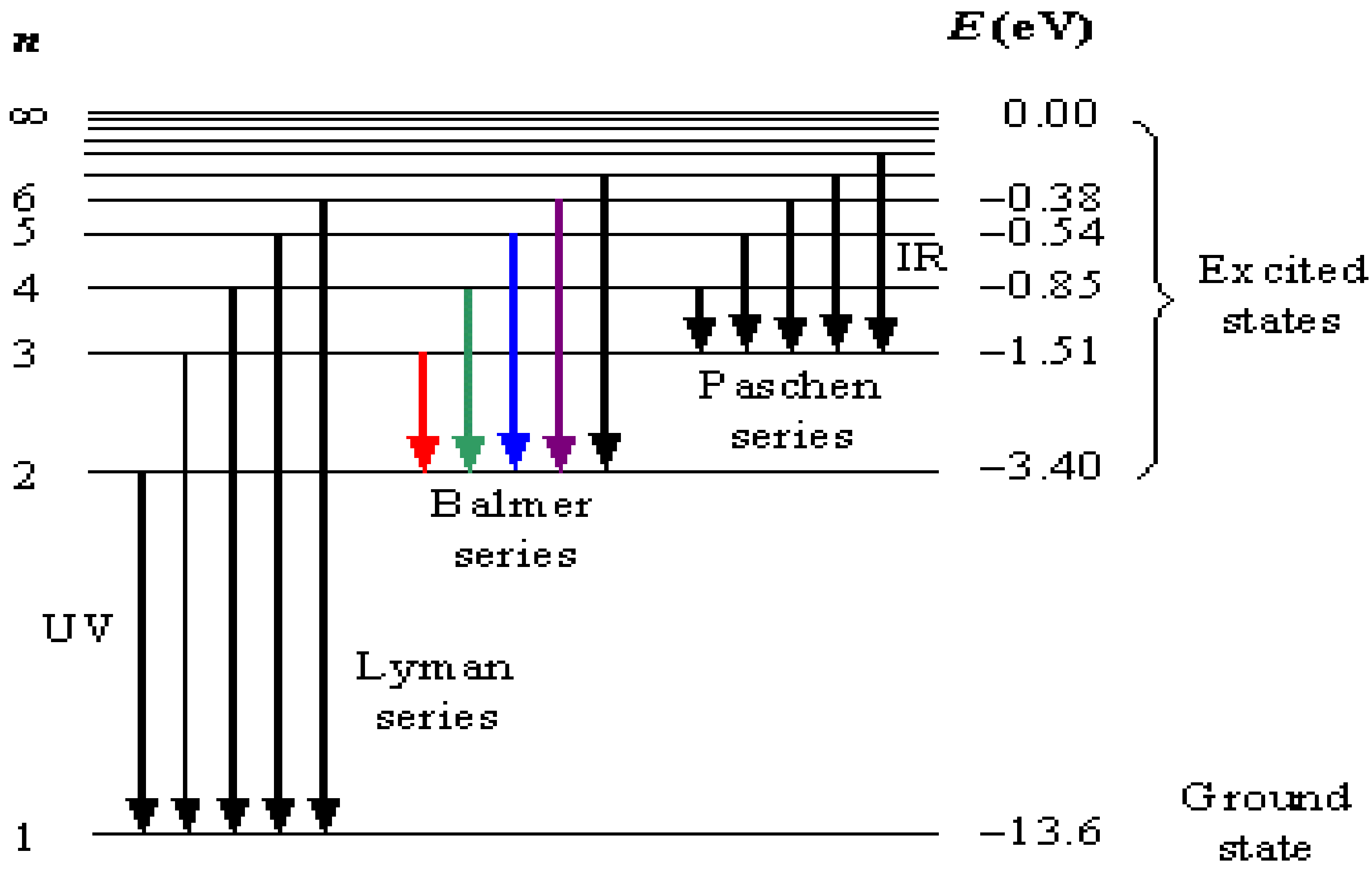
Explanation of Atomic Spectra

- The lowest possible energy of the electron is the ground state.

The light emitted by an electron moving from a higher to a lower energy level has a frequency directly proportional to the energy change of the electrons.

E = h x v

h= 6.626 x 10^ -34 J.s

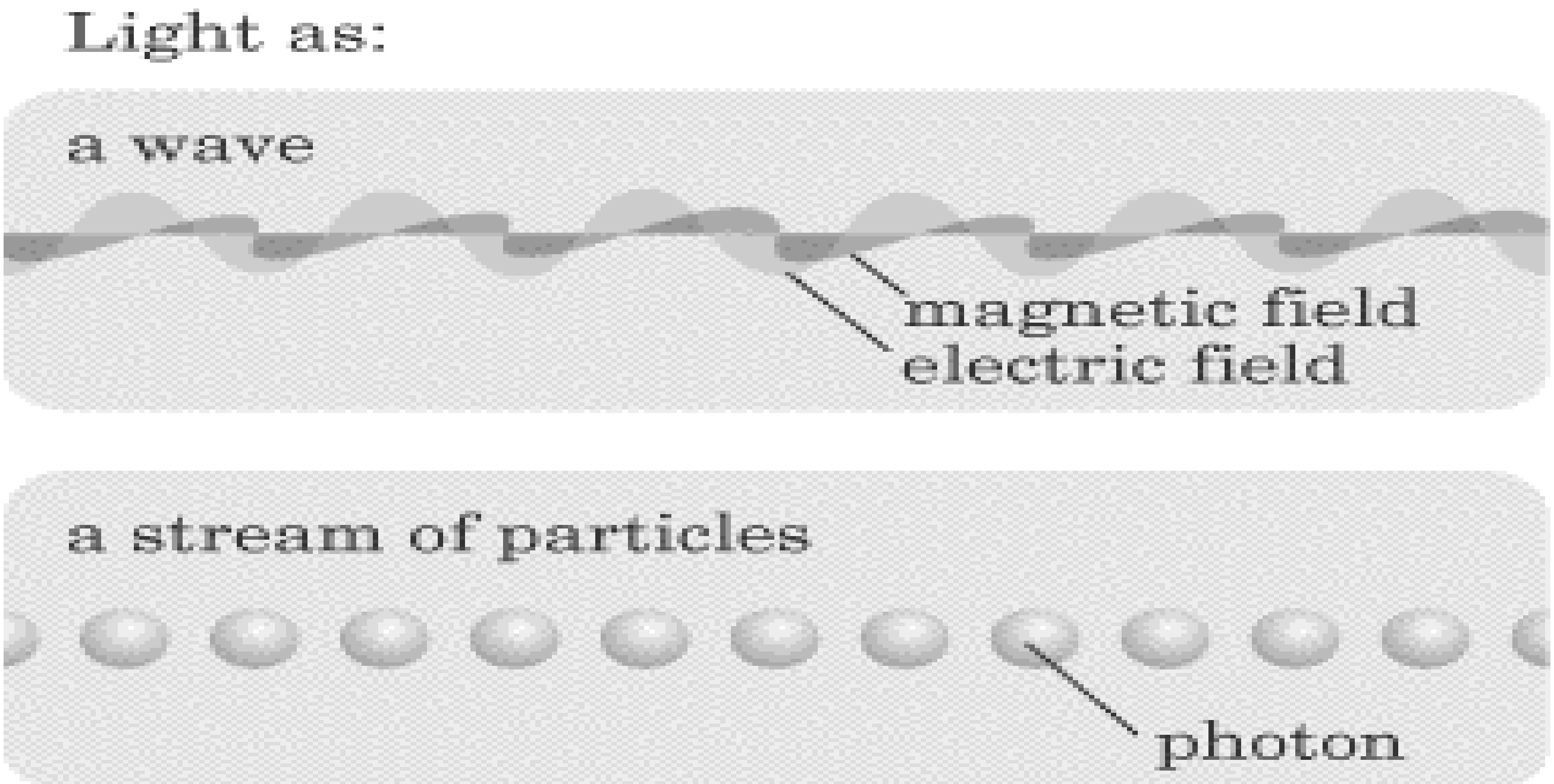


Energy levels of the hydrogen atom with some of the transitions between them that give rise to the spectral lines indicated.

The Quantum Mechanical Model

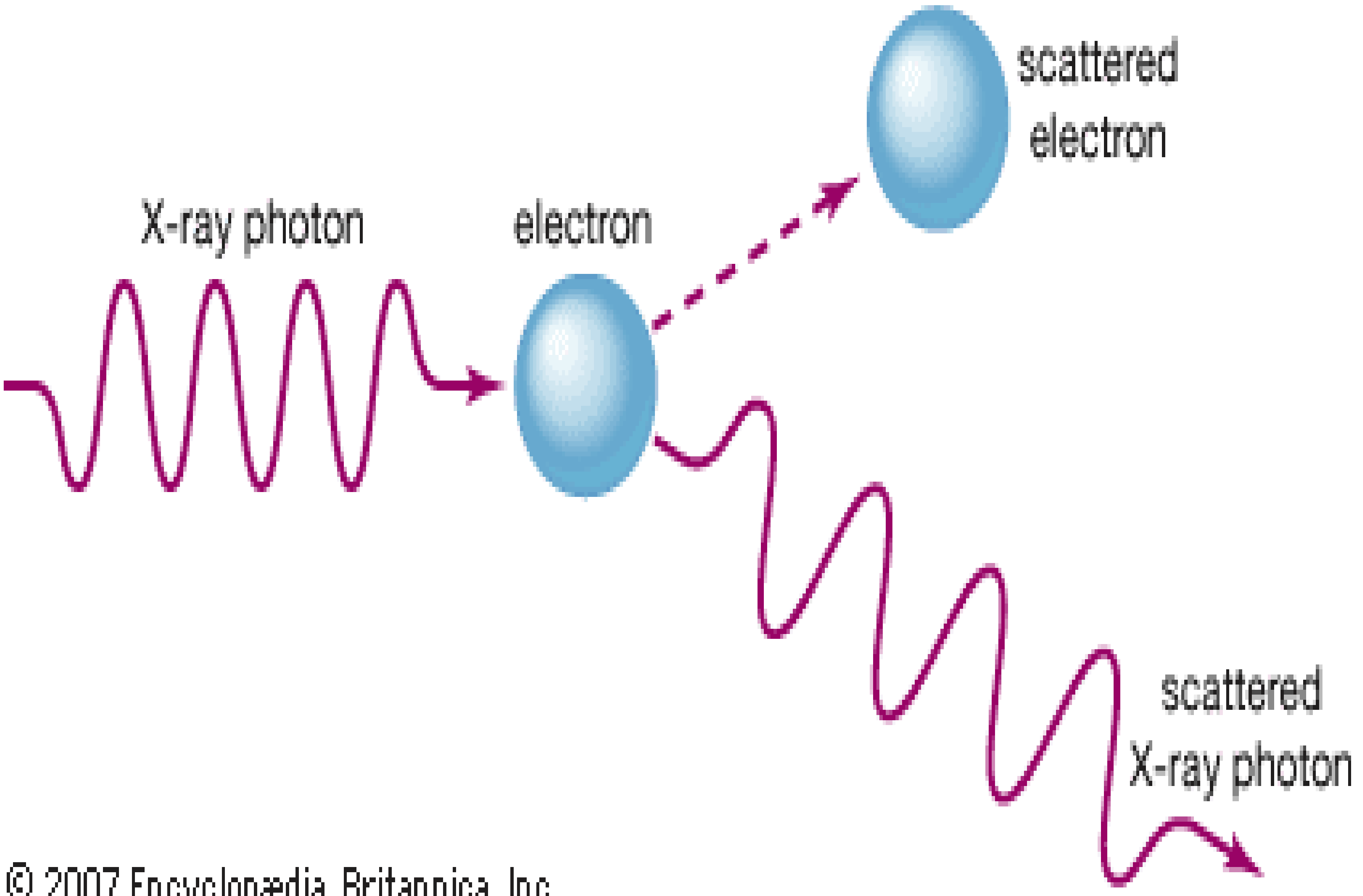
- After Max Planck determined that energy is released and absorbed by atoms in certain fixed amounts known as **quanta**, Albert Einstein took his work a step further,determining that radiant energy is also quantized—he called the discrete energy packets **photons**. Einstein's theory was that electromagnetic radiation (light, for example) has characteristics of both a wave and a stream of particles.

Quanta of Light



Quantum Mechanics

- **Classical mechanics adequately describes the motions of bodies much larger than atoms, while quantum mechanics describes the motions of subatomic particles and atoms as waves.**
- **The Heisenberg Uncertainty principle states that it is impossible to know exactly both the velocity and the position of a particle at the same time.**


X-ray photon
electron
scattered
electron
scattered
X-ray photon