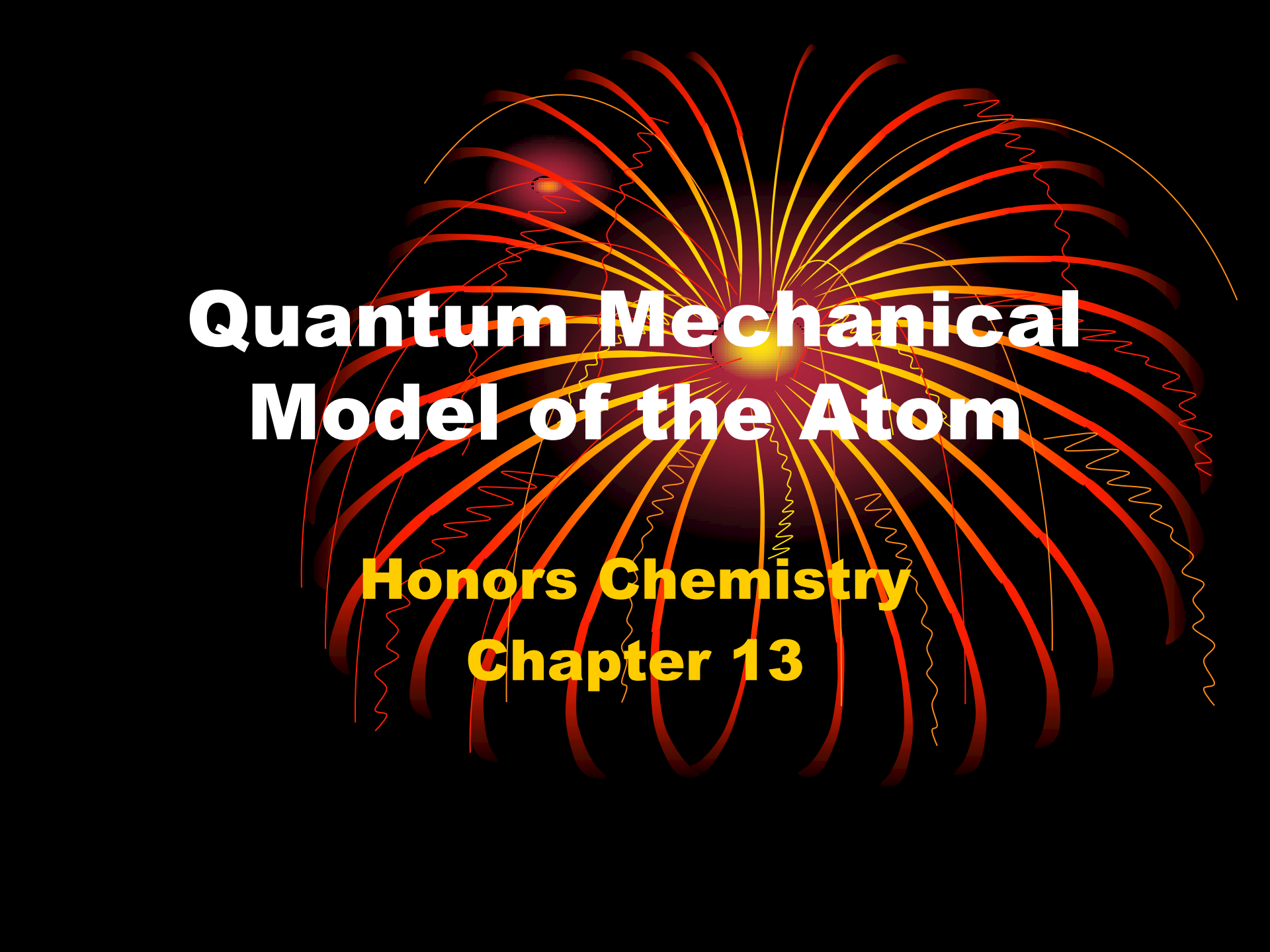
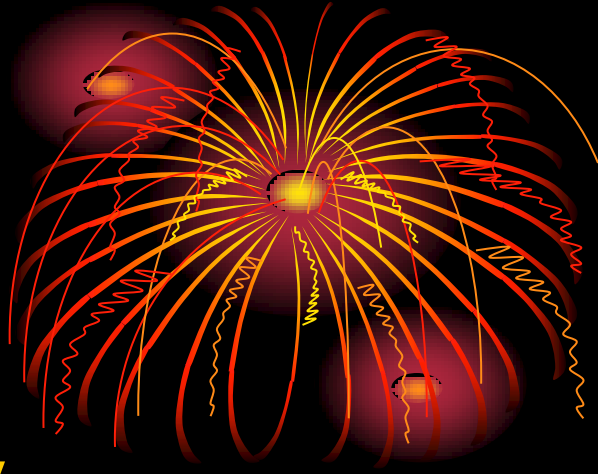


Quantum Mechanical Model of the Atom

Honors Chemistry
Chapter 13

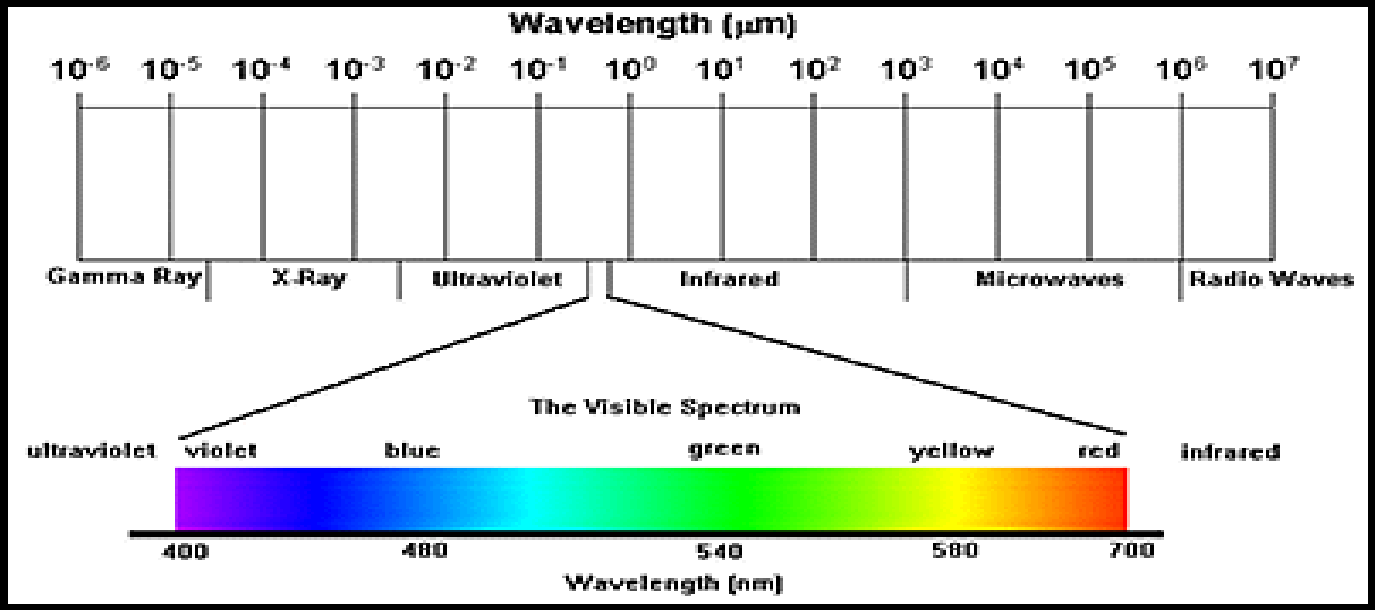
Let's Review

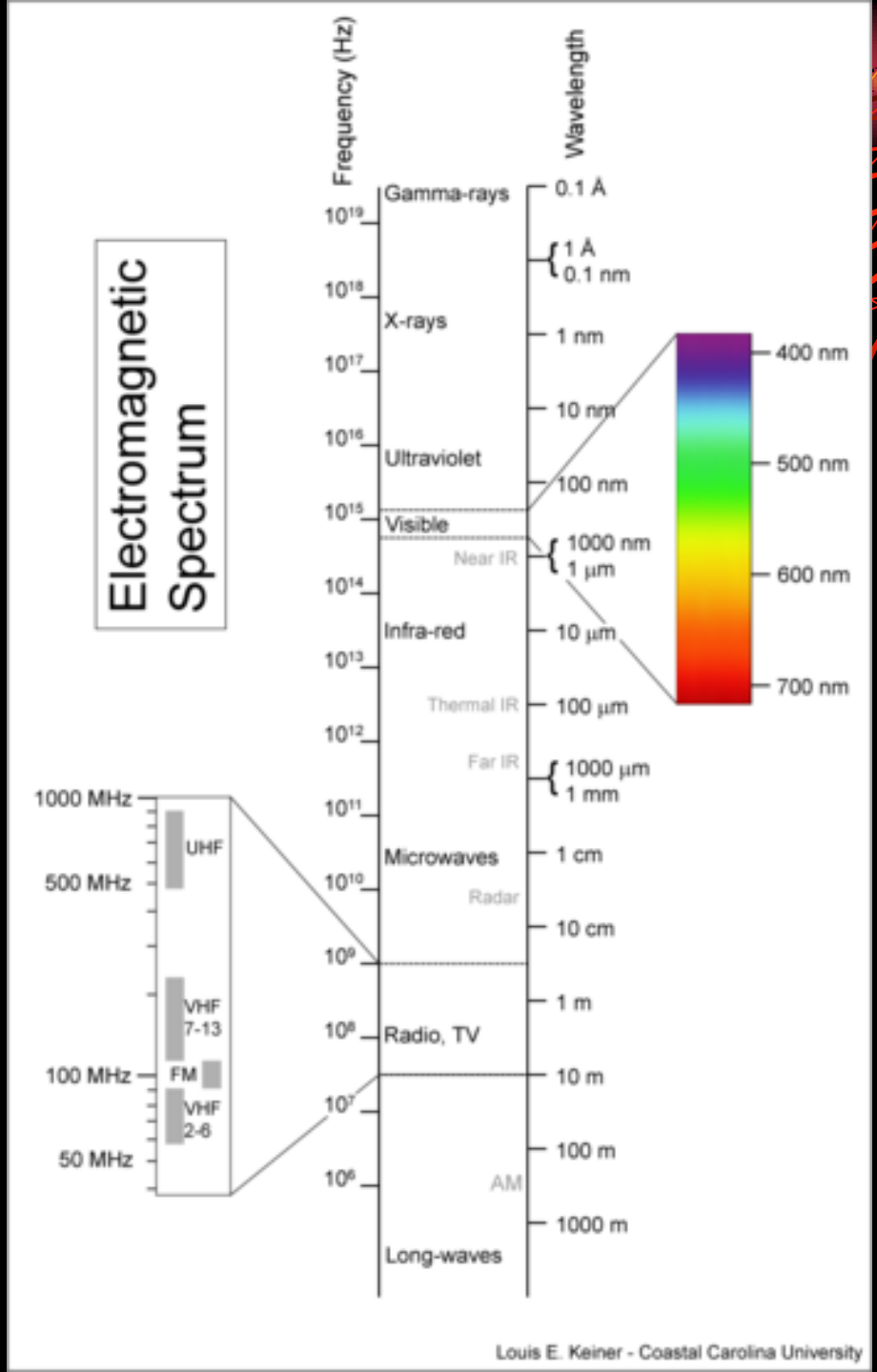


- Dalton's Atomic Theory
- Thomson's Model – Plum Pudding
- Rutherford's Model
- Bohr's Model – Planetary
- Quantum Mechanical Model – cloud of probability

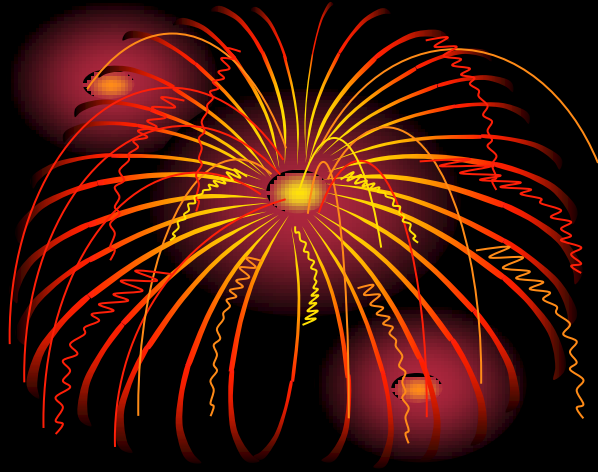
Study of Light

- **Light consists of electromagnetic waves.**
- **Electromagnetic radiation includes the following spectrum.**

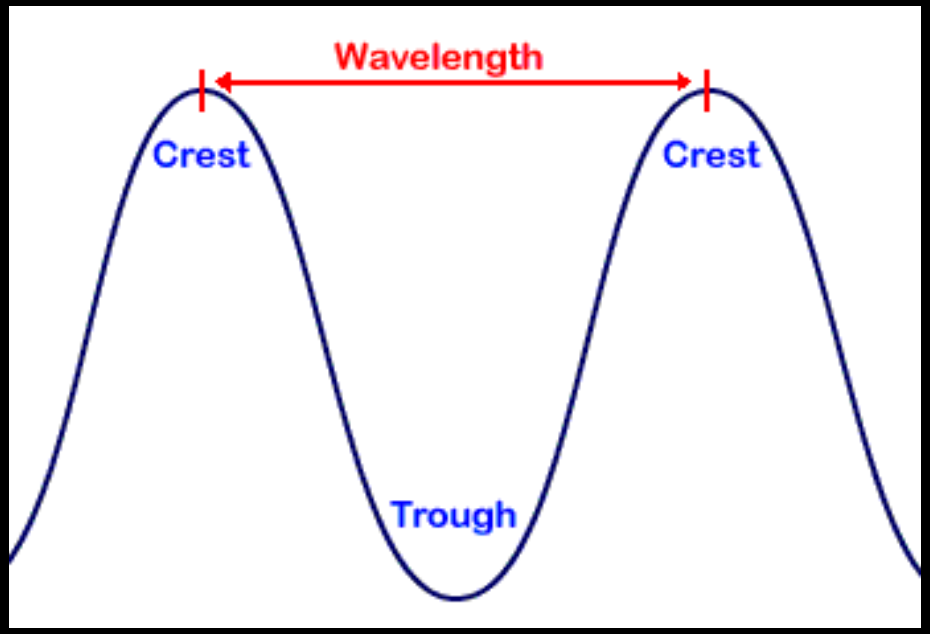


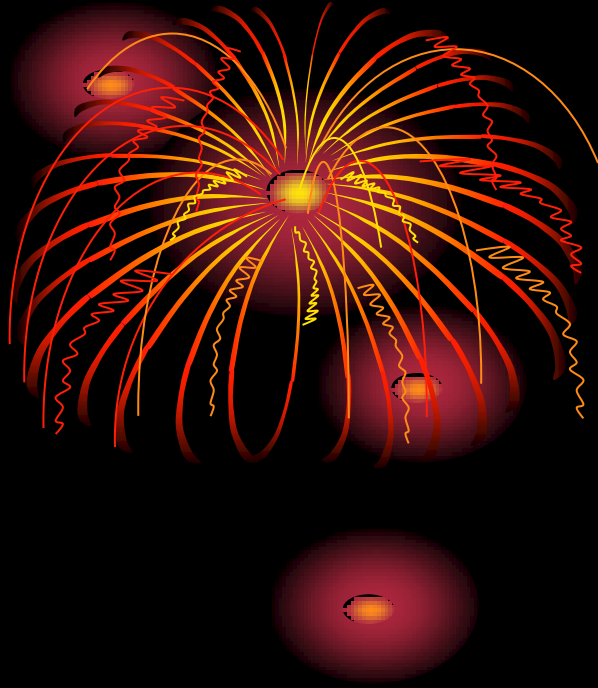

Electromagnetic Spectrum
Frequency (Hz)
Wavelength
Gamma-rays
X-rays
Ultraviolet
Visible
Near IR
Infra-red
Thermal IR
Far IR
Microwaves
Radar
Radio, TV
AM
Long-waves
10^{19}
10^{18}
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
0.1 Å
1 Å
0.1 nm
1 nm
10 nm
100 nm
1000 nm
1 µm
10 µm
100 µm
1000 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1000 m
400 nm
500 nm
600 nm
700 nm
1000 MHz
500 MHz
100 MHz
50 MHz
UHF
VHF 7-13
FM
VHF 2-6
Louis E. Keiner - Coastal Carolina University

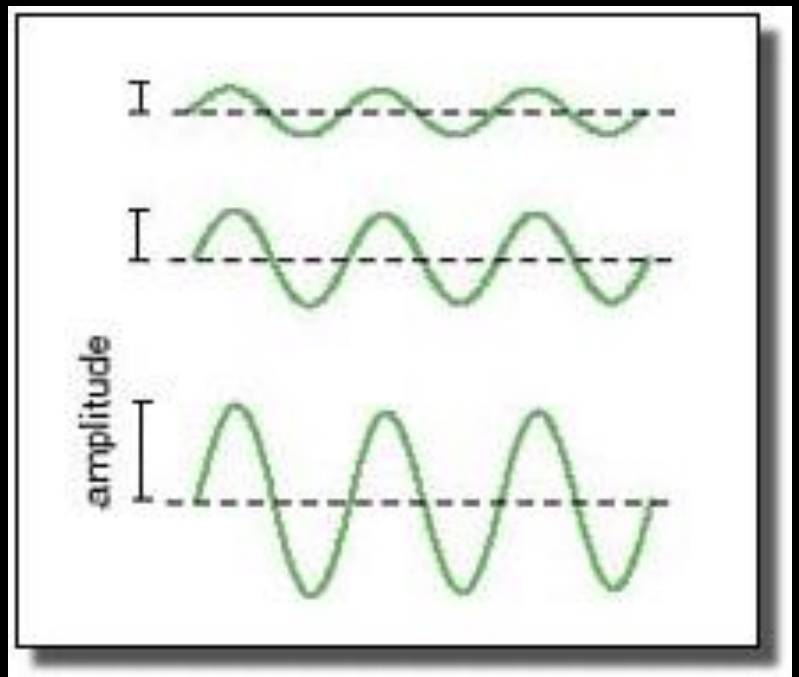
Waves

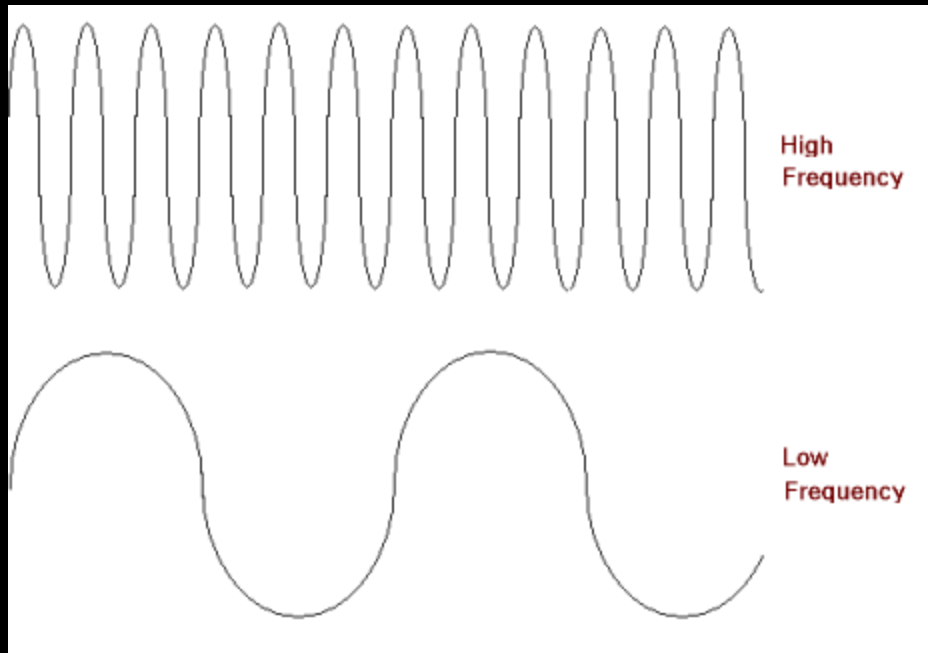


- Parts of a wave:
  - Amplitude, crest, trough
- Wavelength – distance from crest to crest or trough to trough
- Frequency – how many waves pass a point during a given unit of time


Wavelength
Crest
Crest
Trough




amplitude


High
Frequency
Low
Frequency

Wave Equations

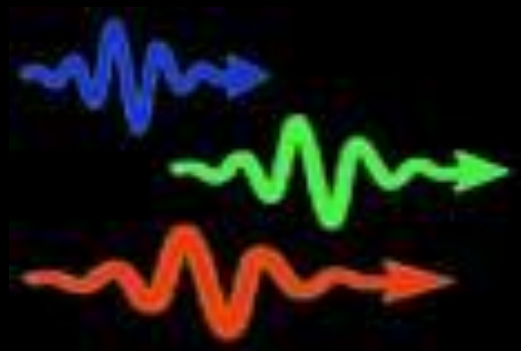
Frequency is inversely related to the wavelength by the speed of light.

$$c = \lambda\nu$$

where λ = wavelength, ν = frequency, and c = speed of light = 3×10^8 m/s

Dual Nature of Light

- Light also has properties of particles.
- These particles have mass and velocity.
- A particle of light is called a photon.



Energy

How much energy is emitted by a photon of light can be calculated by

$$E = h\nu$$

where

E = energy of the photon,

h = Planck's constant = 6.626×10^{-34} J s

ν = frequency

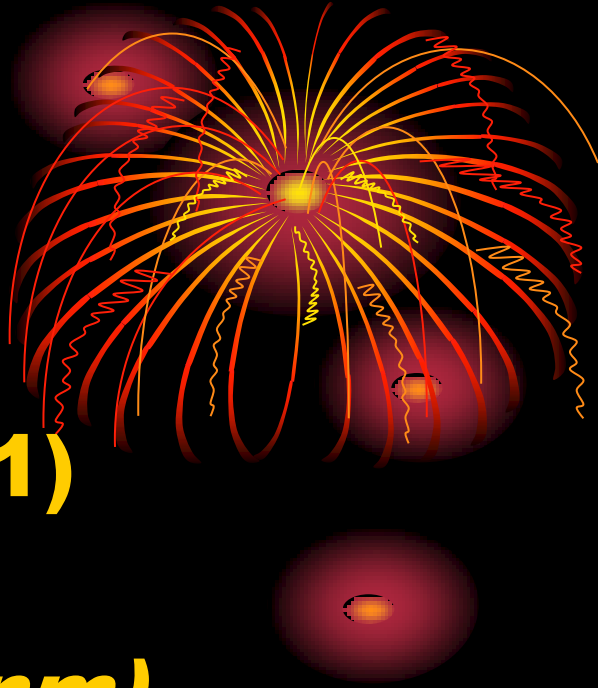
Wave and Particle

To relate the properties of waves and particles, use DeBroglie's equation:

$$\lambda = h/mv$$

Where λ = wavelength, h = Planck's constant, m = mass and v = velocity.

Typical Units



ν = waves per second (s-1)

λ = meters, (m)

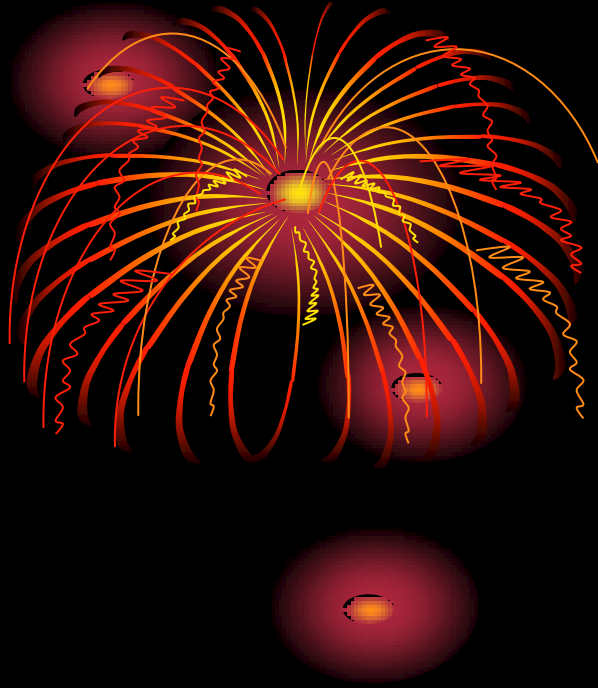
(note: 1 m = 1 x 10^9 nm),

E = Joules (J),

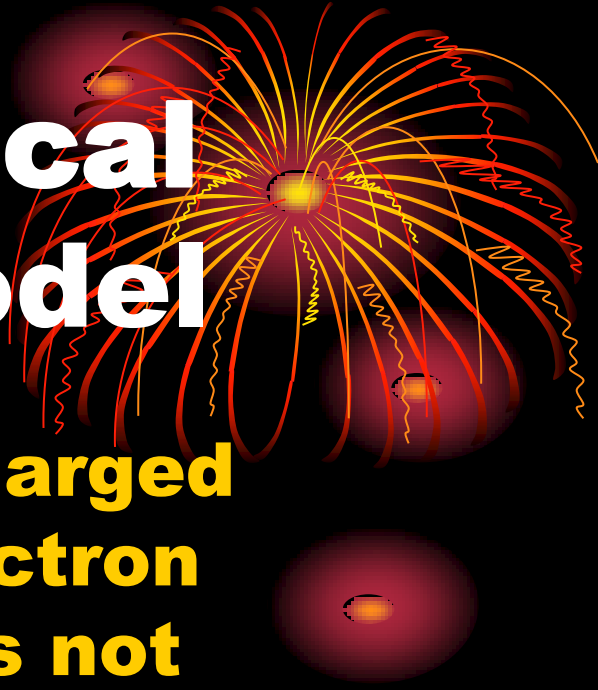
h, Planck's constant = Joules x Seconds, (J s)

m = kilograms

v = meters per second, m/s



Quantum Mechanical Model or Wave model



- **Small, dense, positively charged nucleus surrounded by electron clouds of probability. Does not define an exact path an electron takes around the nucleus.**

- **Electron cloud – the volume in which the electron is found 90% of the time**

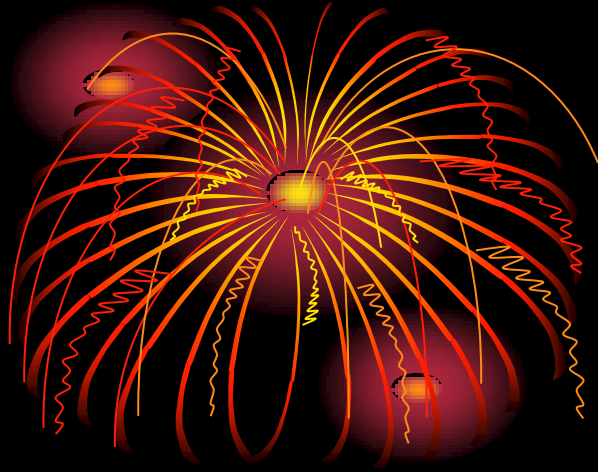
- **Energy Level – the region around a nucleus where an electron is likely to be moving.**

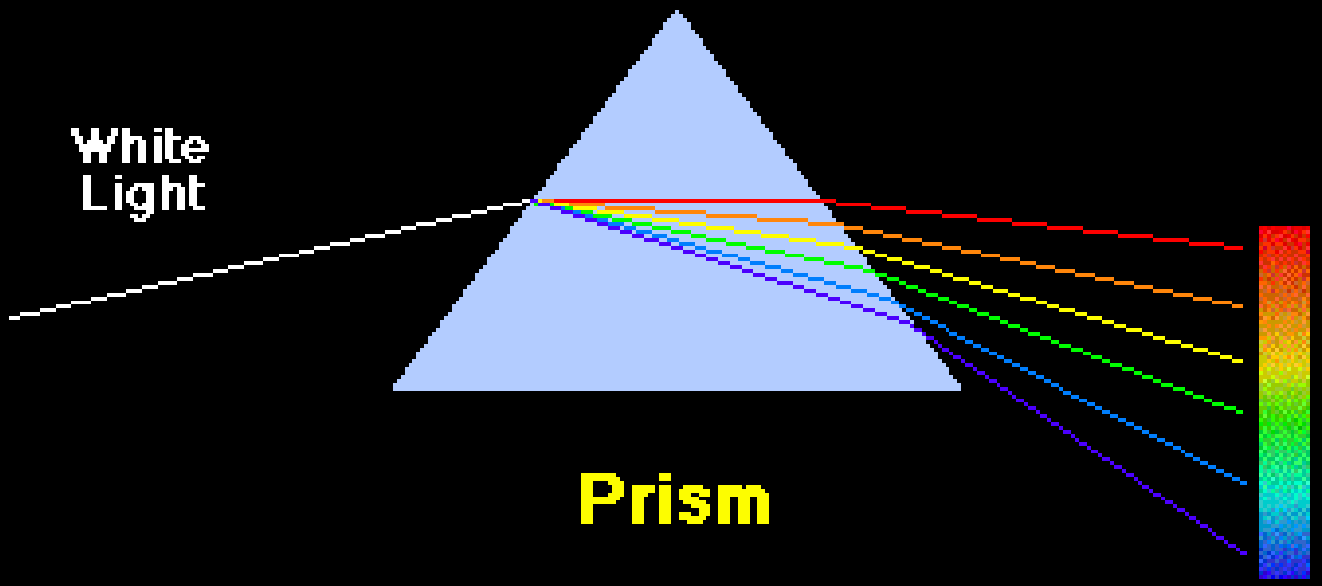
- **<u>Planck's Hypothesis</u> - energy is given off in little packets, or quanta, instead of continuously.**

A Quantum of energy

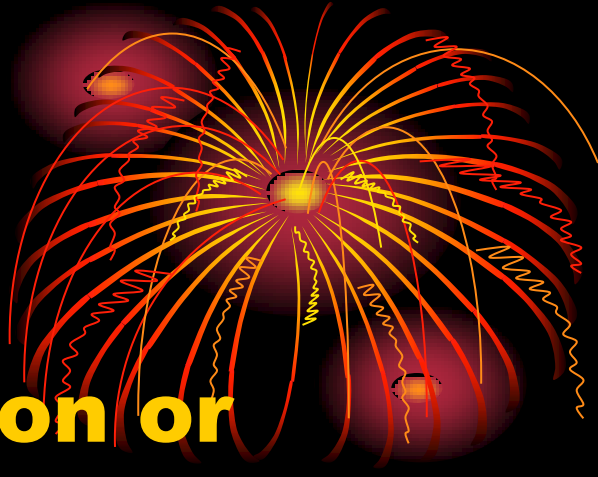
- **A packet of energy or the amount of energy required to move an electron from its present energy level to the next higher one.**

Splitting Light



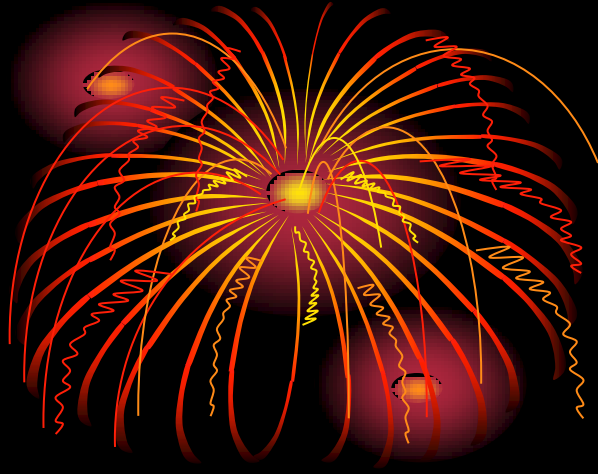


Spectrums

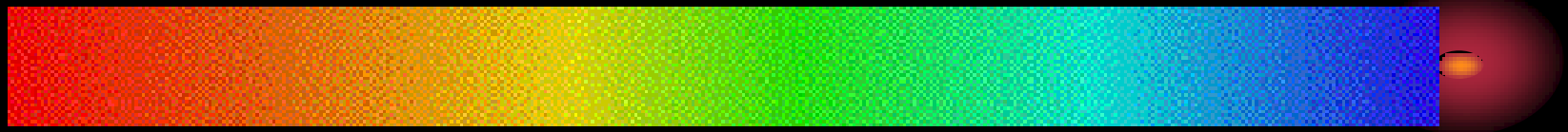


- **The lines on the emission or absorption spectrums of an element are produced when the electrons in that atom change energy levels.**

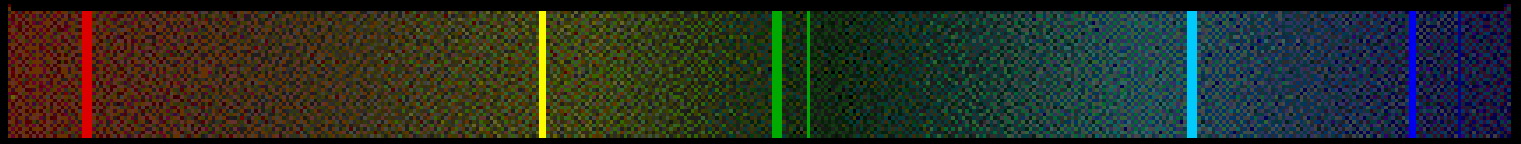
Spectrums



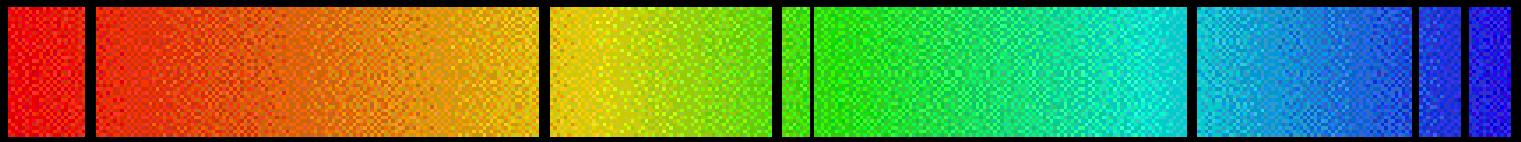
Continuous Spectrum



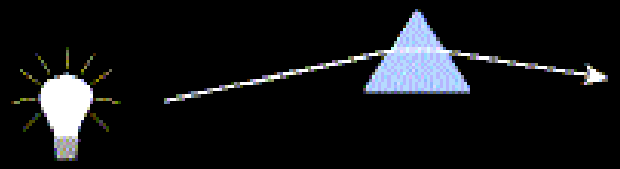
Emission Spectrum



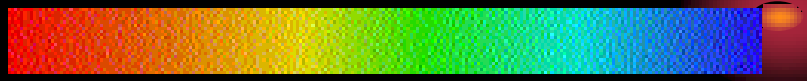
Absorption Spectrum



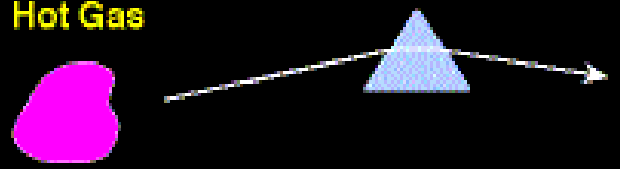
Sources of Spectrums



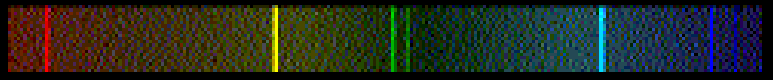
Continuous Spectrum



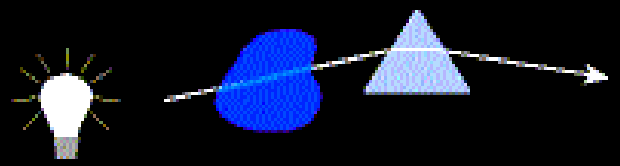
Hot Gas



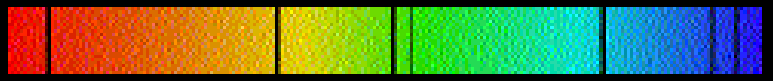
Emission Spectrum



Cold Gas



Absorption Spectrum



Quantum Numbers

- **Used to describe an electron's behavior or likely location**
- **There are four with variables: *n, l, m, & s***

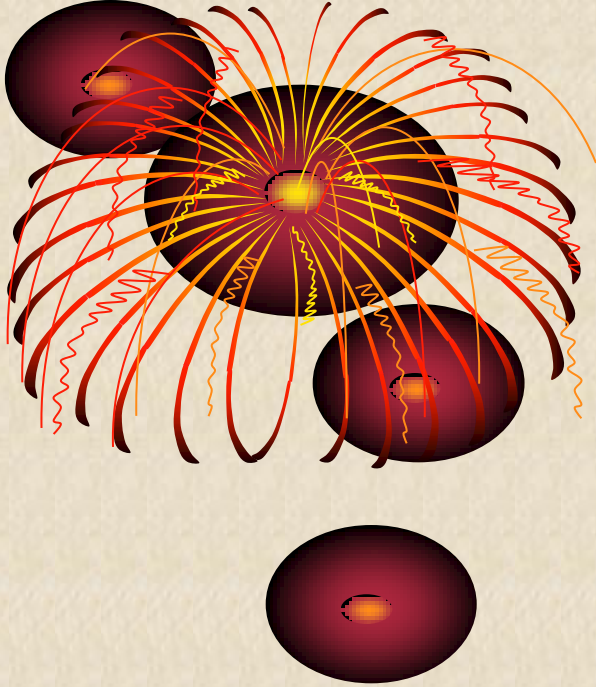
Principal Quantum Number (*n*)

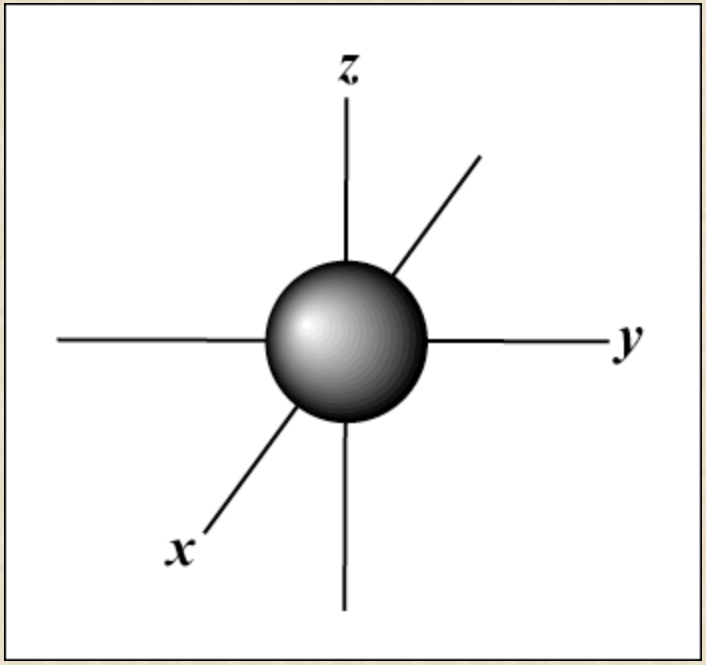
- Corresponds to the energy levels 1 through *n*. However, we will only deal with 1-7.
- Average distance from the nucleus increases with increasing principal quantum number, therefore *n* designates the size of the electron cloud
- Maximum # of electrons in each energy level is calculated by $2n^2$ where *n* = the energy level (1-7).

Energy Sublevels (*l*)

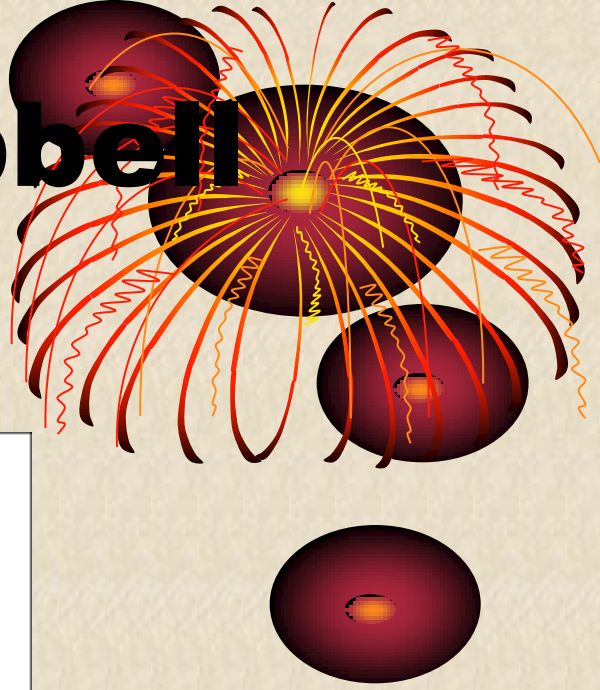
- 2nd quantum number
- The number of sublevels equals the value of the principal quantum number (*n*) for that level.
- Sublevels are named in the following order - s, p, d, f.
- The *l* number designates the shape of the electron cloud.

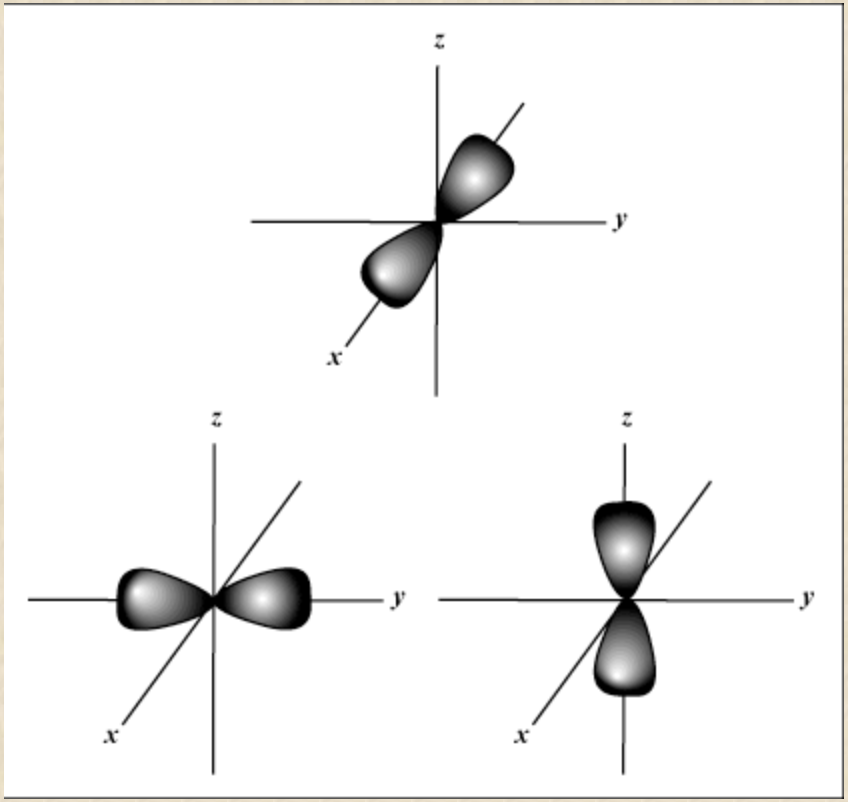
S sublevel – spherical shape



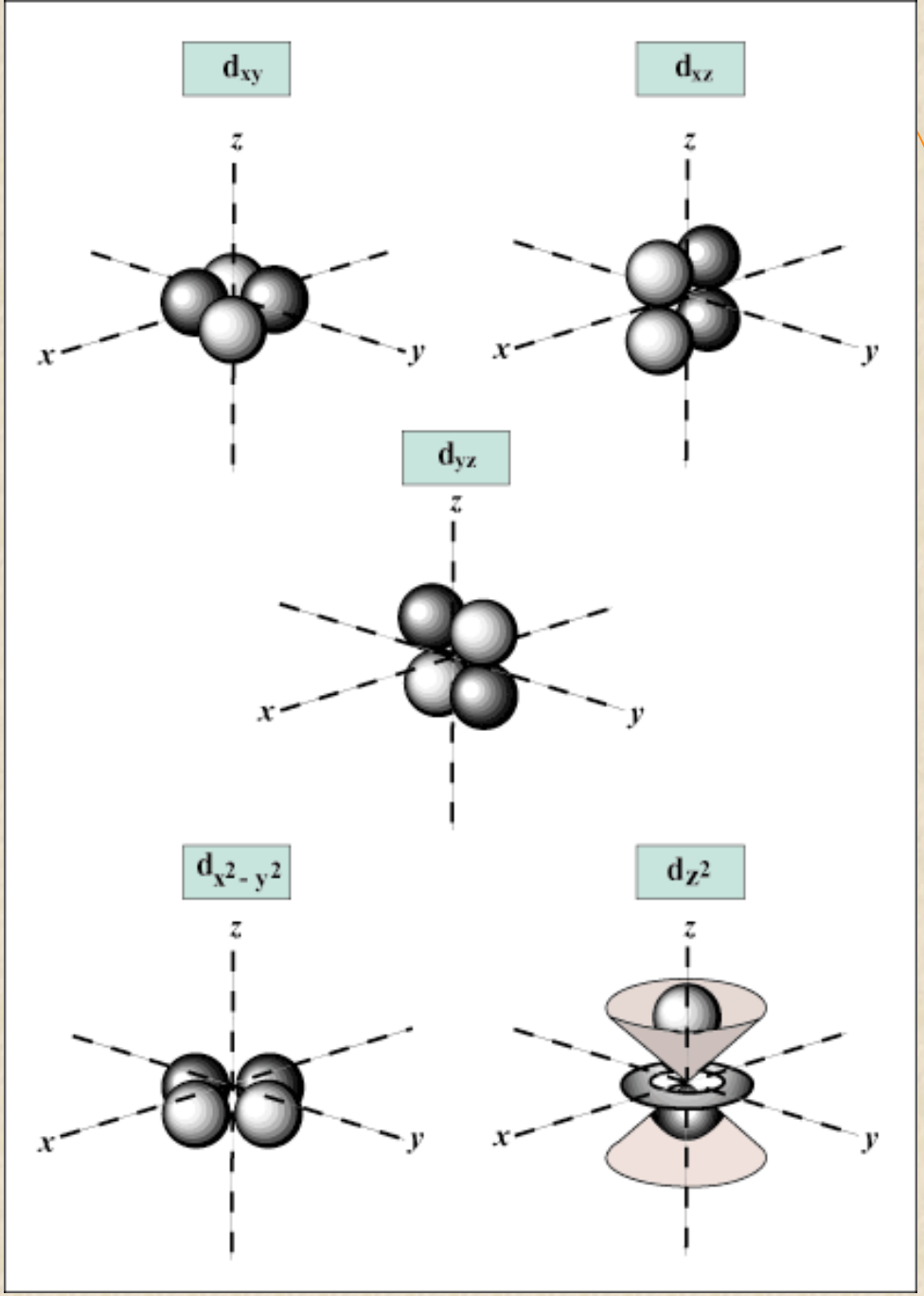


P sublevel - dumbbell shaped





D sublevel clover-leaf shaped



F sublevel – irregularly shaped

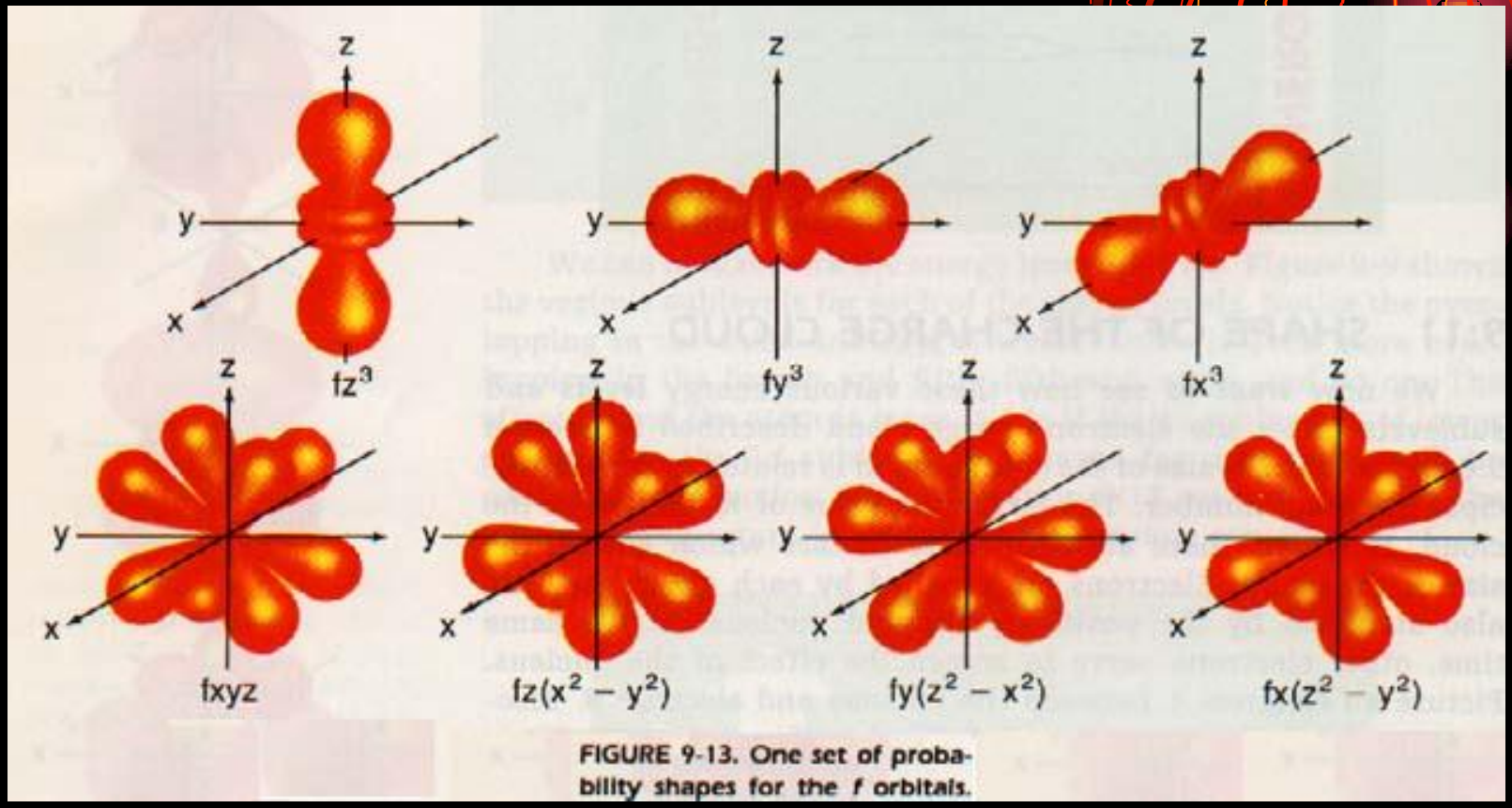
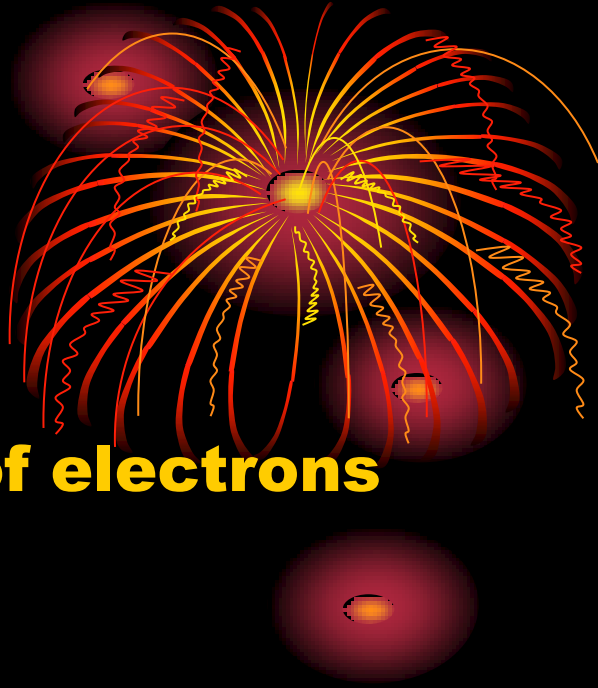


FIGURE 9-13. One set of probability shapes for the *f* orbitals.

Orbitals (m)



- 3rd quantum number (m)
- The space occupied by a pair of electrons in a certain sublevel.

  Sublevel s - 1 orbital

  p - 3 orbitals

  d - 5 orbitals

  f - 7 orbitals

- Each orbital can hold two electrons.
- *m* represents the orientation in space of the orbitals (x axis, y axis, z axis)

Spin (s)

- 4th quantum number
- Distinguishes between the electrons in the same orbital.
- describes the electrons spin as either clockwise or counter-clockwise

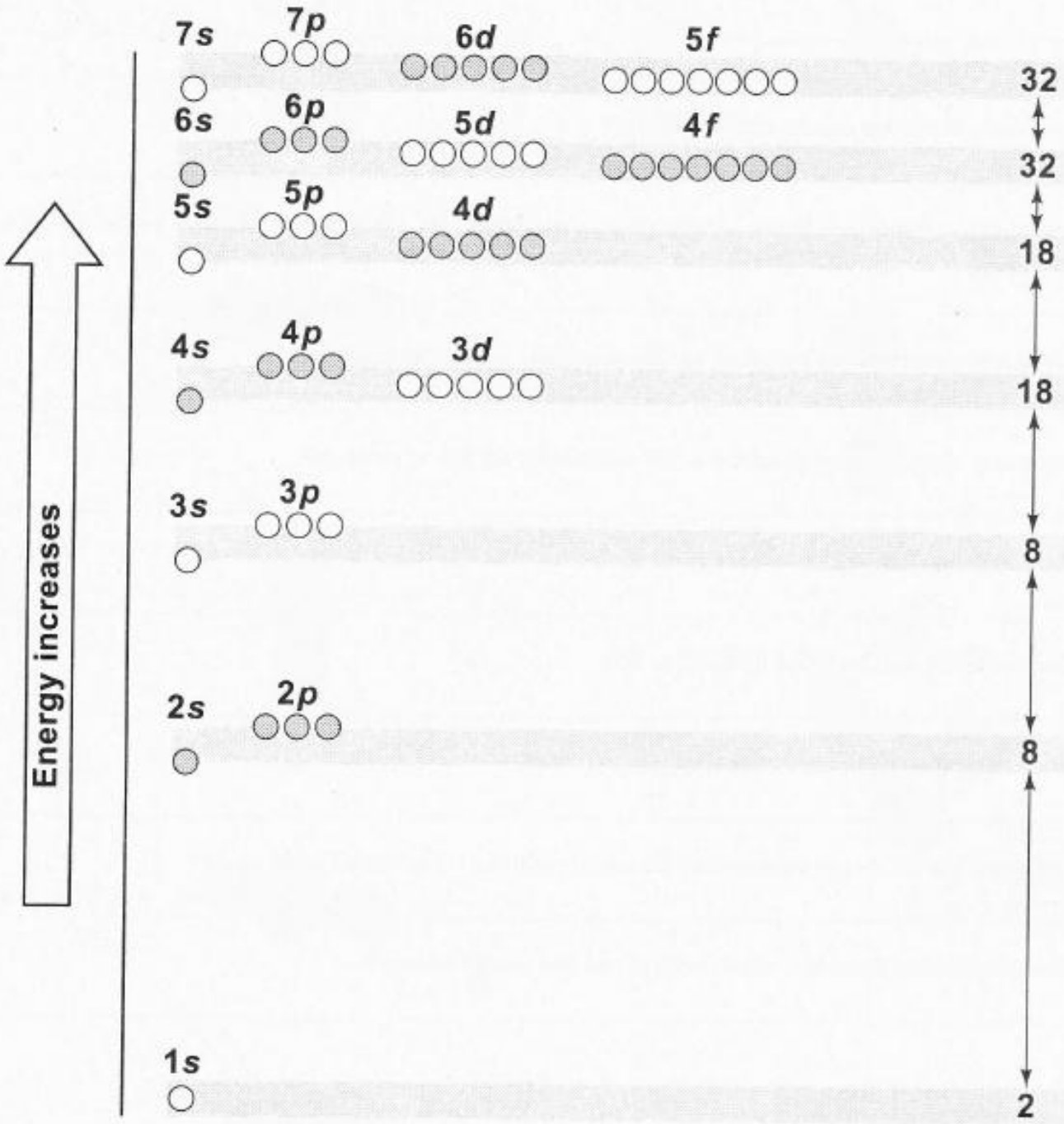
Shape of the electron cloud

- Size (diameter) is related to *n*, the principle quantum number. The larger *n*, the larger the electron cloud.
- Shape is given by the sublevel, (*l*).
- The direction in space is given by the orbital,(*m*).

Electron Configurations

Must follow these rules:

- **Aufbau Principle** – electrons enter orbitals of lowest energy first.
- **Pauli Exclusion Principle** – only 2 electrons can occupy an orbital and they must have opposite spins.
- **Hund's Rule** – When electrons occupy orbitals of equal energy (degenerate orbitals), one electron enters each orbital until all the orbitals contain one with parallel spins, then they will pair up.


Energy increases
7s
7p
6d
5f
6s
6p
5d
4f
5s
5p
4d
4s
4p
3d
3s
3p
2s
2p
1s
32
32
18
18
8
8
2