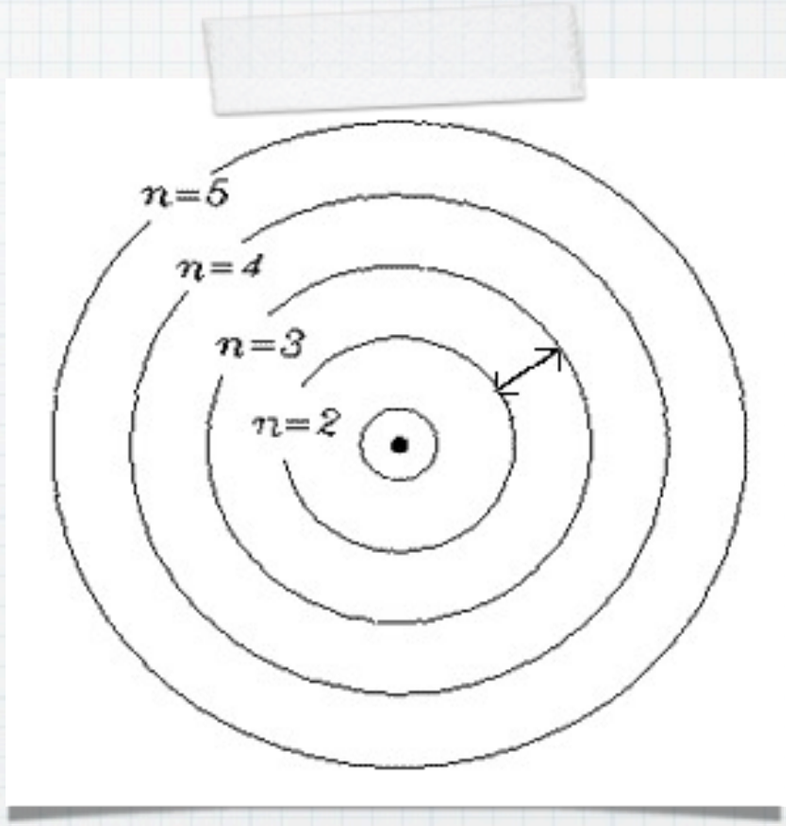
Quantum Mechanical Model of the Atom

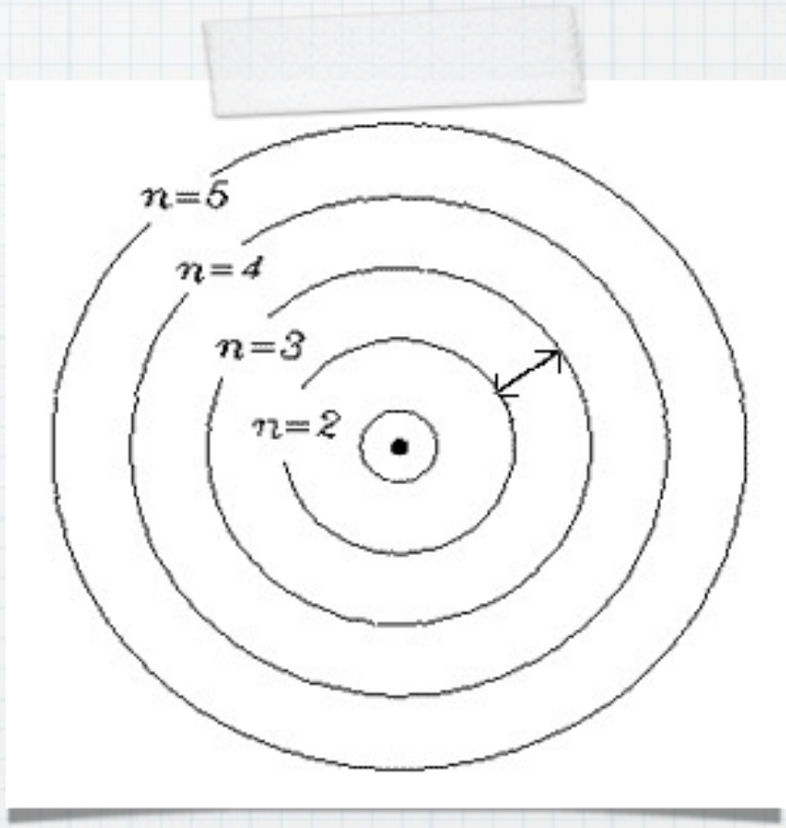
Introducing Quantum Numbers

* A quantum of energy is the amount of energy required to move an electron from one energy level to another.

* The energy levels are like the rungs of a ladder but are not equally spaced.



* Bohr suggested the idea of orbits, and that electrons can jump from one orbit to another.



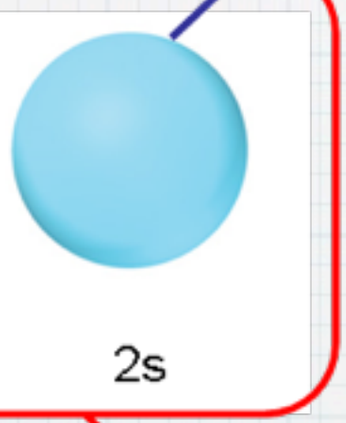
* One major problem with Bohr's model was it was virtually impossible to predict the exact location of a particle as fast or small as an electron.

* The term orbit was discarded and the term orbital was adopted.

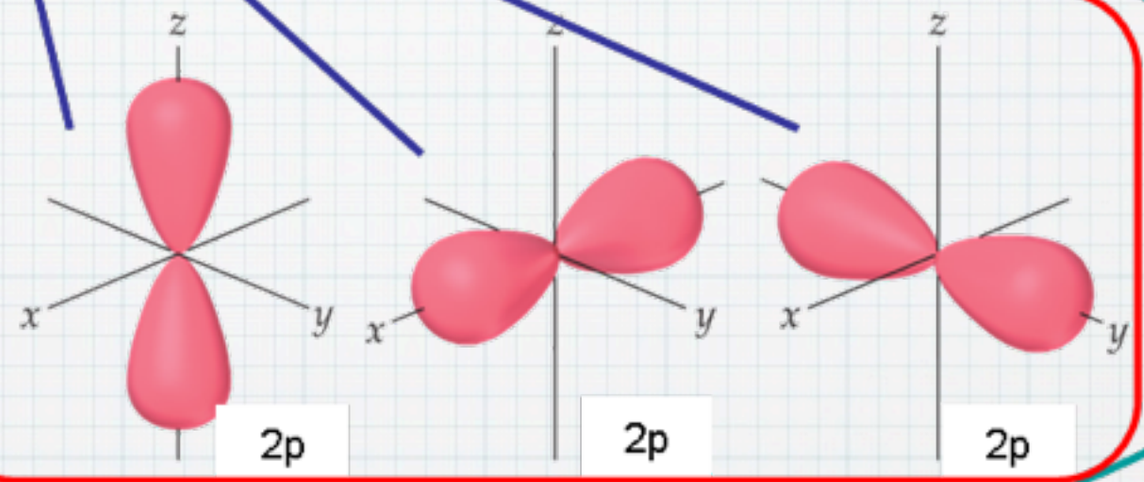
* **Orbit:** An orbit is a 2D circular path the electrons travel around the nucleus.

* **Orbital:** A 3D region in space where the probability of finding an electron is very high (mathematically determined probability function)

orbitals



2s



subshells

shell

Quantum Numbers

* Four quantum numbers are required to describe the state of the hydrogen atom.
    * Principal Quantum Number
    * Orbital Quantum Number
    * Magnetic Quantum Number
    * Spin Quantum Number

Quantum Numbers

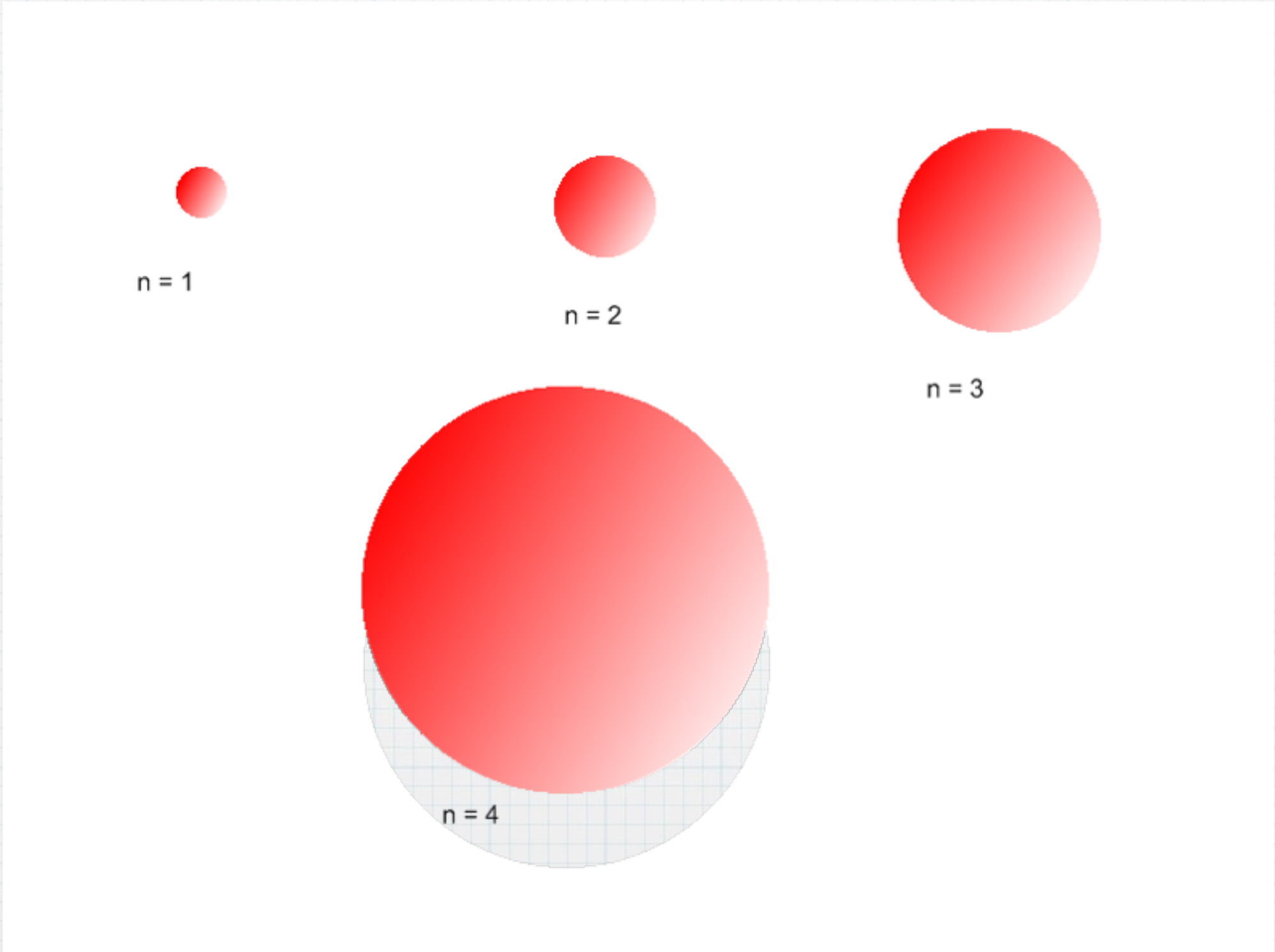
* Principle Quantum Number, n
* One of the major changes to Bohr's model was the splitting of the various energy levels into sublevels. This helped account for the line spectra produced by the multi-electron atoms.

Quantum Numbers

n=1	1st energy level	
n=2	2nd energy level	
n=3	3rd energy level	
n=4	4th energy level	

Quantum Numbers

n=1	1st energy level	no sublevels present
n=2	2nd energy level	2 sublevels present
n=3	3rd energy level	3 sublevels present
n=4	4th energy level	4 sublevels present


n = 1
n = 2
n = 3
n = 4

Quantum Numbers

* **Orbital Quantum Number, ℓ**

  * The secondary quantum number, ℓ, describes the sublevel or the shapes of the orbitals present.

Quantum Numbers

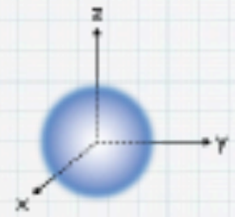
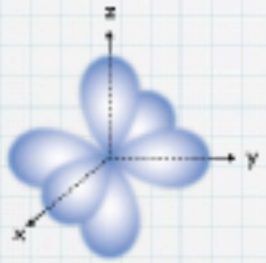
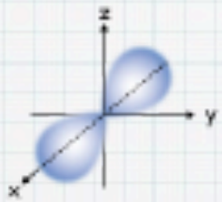
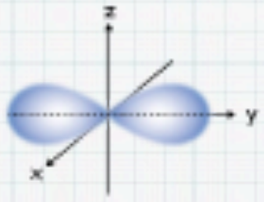
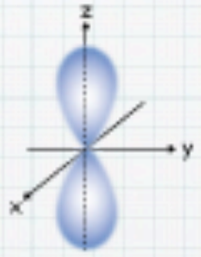
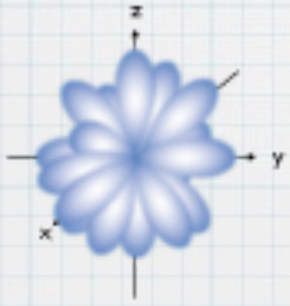
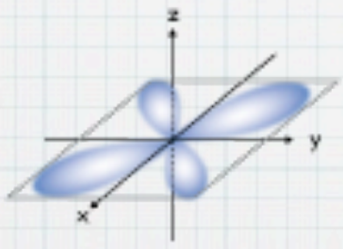
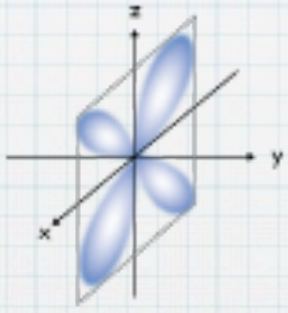
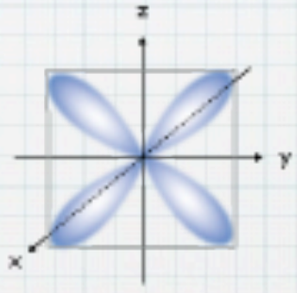
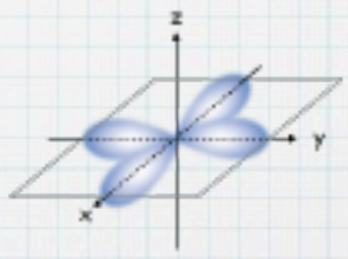
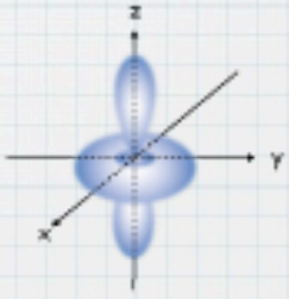
$\ell = 0$	s
$\ell = 1$	p
$\ell = 2$	n
$\ell = 3$	f

Quantum Numbers

$\ell = 0$	s
$\ell = 1$	p
$\ell = 2$	n
$\ell = 3$	f

ℓ ranges from 0 $\rightarrow$ n - 1

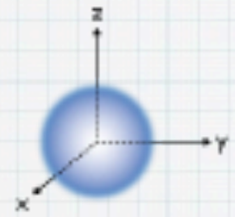
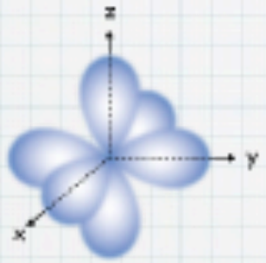
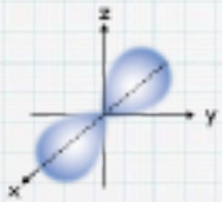
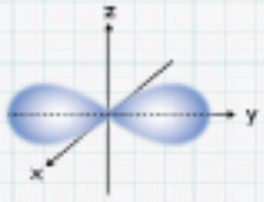
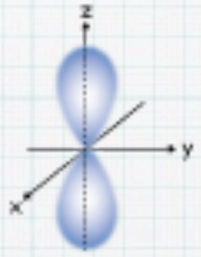
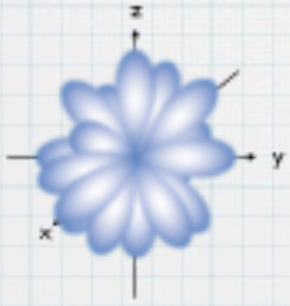
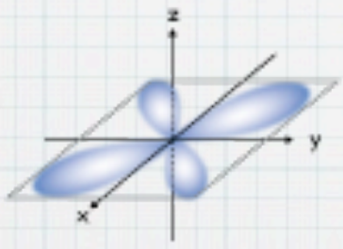
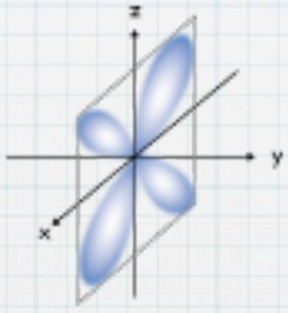
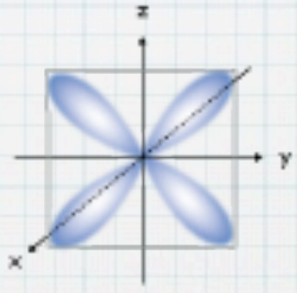
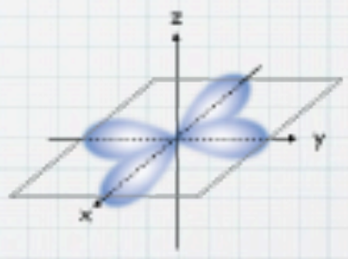
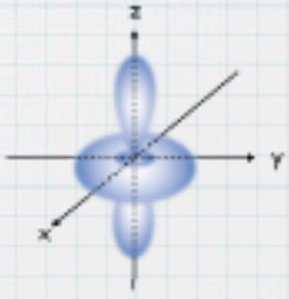
Orbitals and sub-orbitals of Bound Electrons

$\ell = 0$ **s**						
$\ell = 1$ **p**		p_x  $m_\ell = -1$	p_y  $m_\ell = 0$	p_z  $m_\ell = +1$		
$\ell = 2$ **d**		d_{xy}  $m_\ell = -2$	d_{xz}  $m_\ell = -1$	d_{yz}  $m_\ell = 0$	$d_{x^2-y^2}$  $m_\ell = +1$	d_{z^2}  $m_\ell = +2$
$\ell = 3$ **f**	7 sub-orbitals not pictured					

Quantum Numbers

* **Magnetic Quantum Number, m_ℓ**
  * Indicates orientation of orbital in space.
  * Values can range from - ℓ to + ℓ
    * Example: when ℓ = 1, possible values of ℓ may include -1, 0, +1

Orbitals and sub-orbitals of Bound Electrons

$\ell = 0$ **s**						
$\ell = 1$ **p**		p_x  $m_\ell = -1$	p_y  $m_\ell = 0$	p_z  $m_\ell = +1$		
$\ell = 2$ **d**		d_{xy}  $m_\ell = -2$	d_{xz}  $m_\ell = -1$	d_{yz}  $m_\ell = 0$	$d_{x^2-y^2}$  $m_\ell = +1$	d_{z^2}  $m_\ell = +2$
$\ell = 3$ **f**	7 sub-orbitals not pictured					

Quantum Numbers

* Spin Quantum Number, m_s
  * Indicates the spin of electron.
  * Can only have two values, +1/2 or -1/2.
  * Represent clockwise or counterclockwise spin.

Quantum Numbers

* In a given atom no two electrons can have the same set of quantum numbers (n, ℓ, m_ℓ, m_s)
* Since electrons in the same orbital have the same n, ℓ, and m_ℓ this means they must have opposite m_s

Overview

Name	Symbol	Allowed Value	Property
Principal	n	Positive Integers	Energy Level
Secondary (Orbital)	ℓ	$0 \rightarrow n - 1$	Orbital Shape
Magnetic	m_ℓ	$-\ell \rightarrow +\ell$	Orientation
Spin	m_s	$+1/2 \rightarrow -1/2$	Spin