Quantum Numbers

Describing Orbitals

The Principal Quantum Number

- Similar to shells or energy levels of the Bohr model
- **Values:** Represented by the principal quantum number, *n*
  - has integral values, 1 through 7
  - same as the period number in periodic table
- **Significance:** Related to the size and energy of the orbital
  - as *n* increases
    - the orbitals becomes larger and the electrons spend more time further away from the nucleus
    - the electrons are less tightly bound to the nucleus and have higher energy

The Angular Momentum Quantum Number

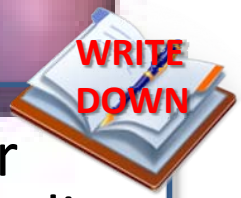
- Corresponds to the *subshells* or *sublevels*
- **Values:** Represented by the angular momentum quantum number, ℓ
  - Has integral values from **0 to *n*–1**
  - **Example:** What are the values of ℓ when $n = 3$?

    $\ell = \{ 0, 1, 2 \}$
  - As a result, the maximum number of subshells in a principal energy level is *n*
- **Significance:** Relates to sublevel energy and the shape of the orbitals

Sublevels

- Sublevels are designated by letters:
  - ℓ =0 is called ***s***
  - ℓ =1 is called ***p***
  - ℓ =2 is called ***d***
  - ℓ =3 is called ***f***
  - For ℓ >3, the sublevels are named alphabetically, (***g***, ***h***, and ***i***), but there are no atoms with electrons in these locations.
- Sublevel energy
  - The lowest energy sublevel is ***s***
  - Energy increases from ***s*** to ***p*** to ***d*** to ***f*** (and so on)

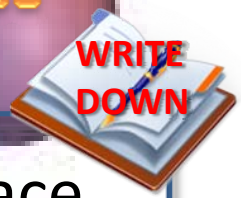
Orbital Shapes



- Orbital shapes are affected by the number of nodes (or pinched in regions where there is zero probability of finding an electron):
  - For ℓ =0 there are no nodes, so ***s*** orbitals are spherical
  - For ℓ =1 there is one node, so ***p*** orbitals have two lobes
  - For ℓ =2 there are two nodes, so ***d*** orbitals have four lobes
  - For ℓ =3 there are three nodes, so most ***f*** orbitals have eight lobes

- Summary Example
  - For n = 2, ℓ = {0, 1} so there are two sublevels, ***s*** and ***p***
  - The ***s*** orbitals have no nodes, and the ***p*** orbitals have one node

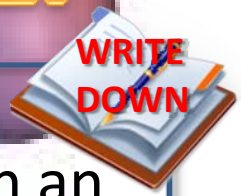
The Magnetic Quantum Number



- Corresponds to the orientation of the orbital in space relative to the other orbitals of the atom
- **Values:** Represented by the magnetic quantum number, m_ℓ
  - has integral values between ℓ and $-\ell$ including 0
  - **Example:** What are the values of m_ℓ when $\ell = 2$?

    $m_\ell = \{-2, -1, 0, 1, 2\}$
- **Significance:** shows the number of orbitals within a sublevel
  - **Example:** When $\ell = 2$ (sublevel *d*) there are 5 values of m_ℓ, so a *d* sublevel has 5 *d* orbitals (in 5 different orientations)

The Electron Spin Quantum Number



- Spectral data indicate that electrons have a magnetic moment with two possible orientations when placed in an external magnetic field
- **Values:** Represented by the electron spin quantum number, m_s
  - Can have only one of two values, +½, or –½
- **Significance:** shows the number of electrons within an orbital
  - Pauli Exclusion Principle - Wolfgang Pauli concluded, in a given atom, no two electrons can have the same four quantum numbers
  - Since any electrons in the same orbital will have the same principal quantum number, angular momentum, and magnetic quantum number, they must have opposite spins to occupy the same orbital
  - Since there are only two spins, the maximum number of electrons in an orbital is 2

Summary

Quantum Number	Symbol	Range
Principle Quantum Number	n	1 to 7
Angular Momentum	ℓ	0 to n–1
Magnetic Quantum Number	m_ℓ	$-\ell$ to ℓ
Spin	m_s	+½, or –½

Sublevel	s	p	d	f
Maximum Number of Orbitals	1	3	5	7
Maximum Number of Electrons	2	6	10	14