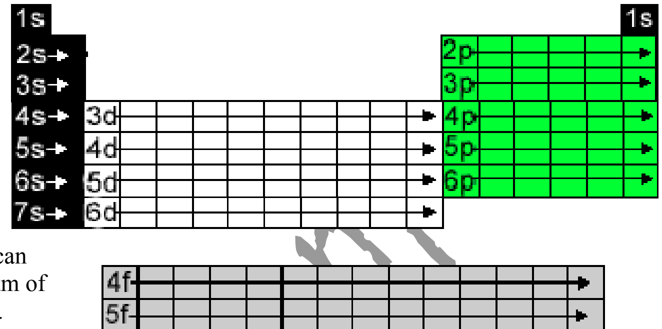
Name ___________________________ **Honors Chemistry** ____/____/____

Electron Configuration & Quantum Numbers

Electron configurations are used to indicate the arrangement of electrons around the nucleus of an atom in its ground state. An electron configuration is made up of numbers and letters. The first number is known as the principle quantum number (n). Each principle quantum number refers to the energy level (or shell) in the atom. **Energy levels tell how far an electron is located from the nucleus**.



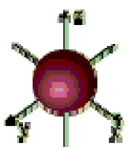
Within each principle energy level, electrons occupy sublevels (or subshells). There are 4 different types of sublevels. Sublevels are represented by the letters **s, p, d & f**. These letters stand for sharp, principle, diffuse and fundamental. These sublevels correspond to different regions of the periodic table as shown to the right.

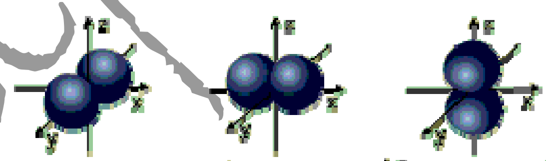
An **s** sublevel can hold a maximum of **2 electrons**. A **p** sublevel can hold a maximum of **6 electrons**. A **d** sublevel can hold a maximum of **10 electrons**. An **f** sublevel can hold a maximum of **14 electrons**.

Since the quantum mechanics model does not limit electrons to a fixed circular path, like the Bohr model, electrons are said to be located in orbitals. **Orbitals are regions of an atom where there is a high probability of finding an electron**. **Each orbital can hold a maximum of 2 electrons**. An s subshell contains 1 s orbital, a p subshell has 3 p orbitals, a d subshell has 5 d orbitals and an f subshell has 7 f orbitals.

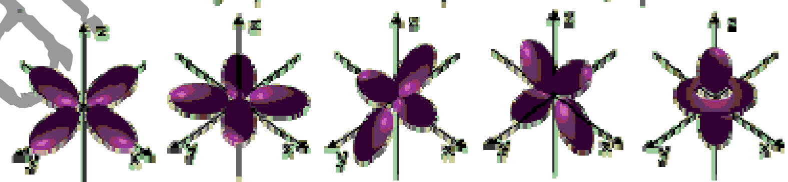
sublevel	# electrons	# orbitals
s	2	1
p	6	3
d	10	5
f	14	7

An s orbital has a spherical shape. A p orbitals have a dumbbell shape.





d & f orbitals are more complex in shape. d orbitals are shown to the right

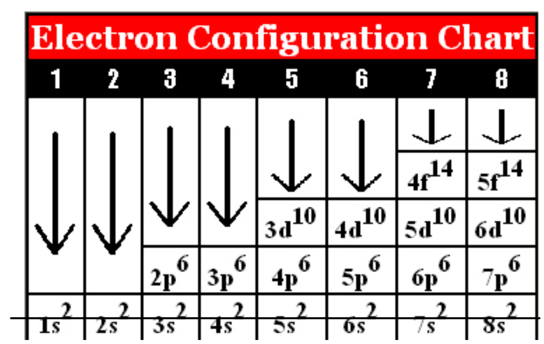


The following rules provide explanations for how electrons are arranged within principle energy levels.

Aufbau Principle - ***Electrons enter orbitals of lowest energy first.***

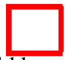
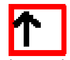
Aufbau is German for "building up." The orbitals of a subshell are all equal. For example, the p subshell has 3 orbitals, p_x, p_y and p_z. All have the same energy. Within an energy level, the s subshell is the lowest energy sublevel. The f subshell is the highest energy sublevel. The p & d sublevels are in the middle but d has more energy than p. (Energy in sublevels: s < p < d < f)

Energy levels sometimes overlap but since *electrons enter orbitals of lowest energy first*, electrons will fill a 4s orbital before a 3d. This is why electron configurations fill in the order they do, even if the energy levels are not in order. (For example, the following snippet in order is: $6s^2\ 4f^{14}\ 5d^{10}\ 6p^6$. A 6s orbital fills before a 4f and 5d because of the Aufbau Principle.)

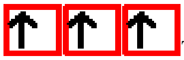


Some transition metals show **exception** in their electron configurations. **Chromium's electron configuration is: $[Ar]4s^1 3d^5$ instead of $[Ar]4s^2 3d^4$ and Copper's electron configuration is: $[Ar]4s^1 3d^{10}$ instead of $[Ar]4s^2 3d^9$. In these elements, an electron is moved from the s to the d subshell so the orbitals are half-filled.** After lanthanum, which has the electron configuration: $[Xe]6s^2 5d^1$, a group of 14 elements called the lanthanide series, or lanthanides, occurs. This series of elements corresponds to filling of the seven 4f orbitals. After actinium, which has the electron configuration: $[Rn]7s^2 6d^1$, a group of 14 elements called the actinide series, or actinides, occurs. This series of elements corresponds to filling of the seven 4f orbitals.

Pauli Exclusion Principle - ***An atomic orbital can describe at most two electrons.***

Atomic orbitals are represented using a box. 
If an orbital contains only one electron, it would be written like this: 
In order for two electrons to fill the same orbital, they must have opposite spins. One spins clockwise and one spins counterclockwise. An orbital with two electrons would look like this: 

Hund's Rule - ***When electrons occupy orbitals of the same energy, electrons will enter empty orbitals first.***
A p subshell with three orbitals would all have one electron with parallel spins before any orbital will gain a second electron.

The example would represent a p^3 subshell.

Quantum Numbers

- Quantum numbers are used to describe the various properties of atomic orbitals.
- **The principle quantum number (*n*)** has integral values: 1,2,3…. The principle quantum number is related to the size and energy of the orbital. As n increases, the orbital becomes larger and the electron spends more time farther from the nucleus.
- **The angular momentum quantum number (ℓ)** or azimuthal quantum number has integral values from 0 to n-1 for each value of n. This quantum number is related to the shape of the atomic orbitals. It is sometimes referred to as subshell.
- **The magnetic quantum number (m_ℓ)** has integral values between ℓ and -ℓ including zero. The value of m_ℓ is related to the orientation of the orbital in space relative to the other orbitals in the atom.
- They found a fourth quantum number was needed to account for the details of the emission spectra of atoms. The spectral data indicated that the electron has a magnetic moment with two possible orientations when the atom is placed in an external magnetic field.
- The new quantum number adopted to describe this phenomenon, called the **electron spin quantum number (m_s)** can have only one of two values, +½ and –½. It really doesn't matter which you pick.
- The main significance of electron spin is connected with the postulate of Austrian physicist Wolfgang Pauli: **In a given atom no two electrons can have the same set of four quantum numbers**. This is called the **Pauli Exclusion Principle**. Since electrons in the same orbital have the same n, ℓ, m_ℓ values, this postulate states that they must have different values of m_s.

Angular Momentum Quantum Number	
Value of ℓ	Letter used
0	s
1	p
2	d
3	f

Follow the steps below to write an electron configuration.
Example: Write the electron configuration for cobalt. Write a set of quantum numbers for one of the **valence electrons.**

Description	Action
Step 1: Find the element on the periodic table and determine how many electrons it has.	**Step 1:** Cobalt is element 27. It has 27 electrons.
Step 2: Begin writing the electron configuration by following the chart until the sum of the superscripts equals the number of electrons you are trying to represent. **Remember:** An s subshell can have up to 2 electrons; a p subshell can have up to 6 electrons, etc. **The last subshell can contain less than the maximum number of electrons**.	**Step 2:** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^7$ $2 + 2 + 6 + 2 + 6 + 2 + 7 = 27$ **Note:** The last subshell only contains 7 electrons. d subshells can have a maximum of 10 electrons.
Step 3: Quantum numbers of **valence electrons**. The valence electrons are in 4s.	**Step 3:** **4** (distance from the nucleus), **0** (subshell, s), **0** (m_l), **+½ or –½** (m_s) – choose either. **One possible set of quantum numbers: 4, 0, 0, -½**

Follow the steps below to write short cut version of electron configurations.
Example: Write the short cut electron configuration for osmium. Write the quantum numbers for the **highest energy electron.**

Description	Action
Step 1: Find the element on the periodic table and determine how many electrons it has.	**Step 1:** Osmium is element 76. It has 76 electrons.
Step 2: Go back to the last Noble Gas that was passed (atomic number).	**Step 2:** Going back, the last Noble gas was xenon.
Step 3: Write the symbol of the Noble gas in brackets to start your electron configuration. Put the atomic number of the noble gas beneath the symbol to let you know the number of electrons already represented. Take note of the row the Noble gas is in on the periodic table.	**Step 3:** Os: [Xe] 54 Xenon ends the fifth row on the periodic table.
Step 4: Continue your electron configuration using the row after the Noble gas. For example, since xenon ends the fifth row of the periodic table, we should begin with the sixth. Always begin with the s subshell.	**Step 4:**Os: [Xe] 6s 54
Step 5: Continue writing your electron configuration following the chart until you reach the correct number of electrons.	Since osmium is 76, we must represent 76 electrons. **Step 5:** Os: [Xe] $6s^2$ $4f^{14}$ $5d^6$ 54
Step 6: The highest energy electron is $5d^6$.	**Step 6:** **5** (distance from the nucleus), **2** (subshell, d), **-2, -1, 0, 1, 2** (m_l) – choose any one, **+ ½ or –½** (m_s) – choose either. **One possible set of quantum numbers: 5, 2, 0, +½**

Follow the steps below to write an orbital diagram.
Example: Write an orbital diagram for phosphorus. Write a set of quantum numbers for one of the **highest energy electrons.**

Description	Action
Step 1: Find the element on the periodic table and determine how many electrons it has.	**Step 1:** Phosphorus has 15 electrons.
Step 2: Write the electron configuration for the element.	**Step 2:** $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^3$
Step 3: Draw boxes to represent orbitals. Remember an s subshell has 1 orbital (1 box), a p subshell has 3 orbitals (3 boxes), etc.	**Step 3:** $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^3$ [ ] [ ] [ ][ ][ ] [ ] [ ][ ][ ]
Step 4: Fill the boxes with arrows. Remember, electrons fill empty orbitals of a subshell first (Hund's Rule) and electrons in the same orbital have opposite spins (Pauli exclusion principle).	**Step 4:** $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^3$ [↑↓] [↑↓] [↑↓][↑↓][↑↓] [↑↓] [↑][↑][↑]
Step 5: The highest energy electron is $3p^3$.	**Step 5: 3** (distance from the nucleus), **1** (subshell, p), **-1, 0, 1** (m_l) – choose any one, **+ ½ or –½** (ms) – choose either**.** **One possible set of quantum numbers: 3, 1,-1, + ½**

Homework:
Part I: Give a possible set of quantum numbers for the highest energy electron and write full electron configurations for each of the following.

1. Sr

2. Zn

3. I

4. F

5. Cu

Part II: Give a possible set of quantum numbers for the highest energy electron and write short cut electron configurations for each of the following

1. Ar

2. Cd

3. Ca

4. Ge

5. Os

Part III: Give a possible set of quantum numbers for the highest energy electron and write orbital diagrams for each of the following.

1. Se

2. He

3. Sc

4. Al

5. Ni

At the completion of this assignment you will be prepared to take the 18 following Chapter 2 on-line quizzes:

• atomic theory multiple choice quiz 1	• electron quiz 2
• atomic theory multiple choice quiz 2	• principle quantum number quiz
• atomic theory multiple choice quiz 3	• principle quantum number quiz 2
• aufbau highest or lowest energy quiz	• quantum numbers quiz 1
• azimuthal quantum number quiz	• quantum numbers quiz 2
• electron configuration questions quiz	• unpaired electrons quiz
• electron configuration questions quiz 2	• unpaired electrons quiz 2
• electron configuration quiz	• writing electron configuration shortcuts quiz
• electron configuration shortcut quiz	• writing electron configurations quiz