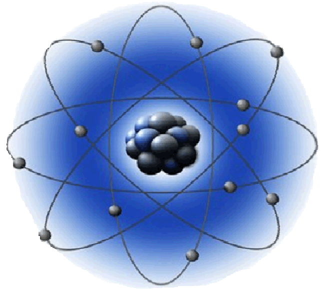
Electron Arrangements



The purpose of this handout is to learn the arrangement of the electrons in the atom. This in turn helps us understand how the elements form compounds through chemical bonding and how chemical reactions take place.

Electron Arrangement Rules

Now that the quantum numbers have been introduced, the possible electron arrangements for the elements in an atom can be described. But, first a few principles need to be stated concerning an atom at ground state.

1. The number of electrons equals the number of protons.
2. The number of electrons each energy level can hold is $\mathbf{2n^2}$.
3. The number of sub shells in an energy level is equal to **n**.
4. The **s** sub shell has only **one** possible position, the **p** sub shell has **three**, the **d** sub shell has **five** and the **f** sub shell has **seven**. Each possible position is an orbital.
5. Only **two** electrons can occupy each orbital.
6. **Hund's Rule:** When a **p**, **d**, or **f** sublevel is being filled, **one** electron will occupy e**ach orbital** before pairing.
7. The **maximum number** of electrons is:
   - two in any s sub shell
   - six in any p sub shell
   - ten in any d subshell, and
   - fourteen in any f sub shell.
8. **Aufbau Principle**: An electron occupies the **lowest** energy level available, filling in orbitals of higher energy levels until all electrons are distributed.
9. **Pauli Exclusion Principle:** No two electrons in an atom have the same four quantum numbers.

Electron Configurations and Orbital Notations

Now lets look at how electron configurations and orbital notations of the elements are represented using our knowledge of quantum numbers.

Example	**electron configuration**	**orbital notation**
hydrogen	$1s^1$	↑
helium	$1s^2$	↑↓
lithium	$1s^2\ 2s^1$	↑↓ ↑ __ __ __
beryllium	$1s^2\ 2s^2$	↑↓ ↑↓ __ __ __
boron	$1s^2\ 2s^2\ 2p^1$	↑↓ ↑↓ ↑ __ __

Complete the following orbital notations

carbon	$1s^2\ 2s^2\ 2p^2$	__ __ __ __ __
nitrogen	$1s^2\ 2s^2\ 2p^3$	__ __ __ __ __
oxygen	$1s^2\ 2s^2\ 2p^4$	__ __ __ __ __
fluorine	$1s^2\ 2s^2\ 2p^5$	__ __ __ __ __
neon	$1s^2\ 2s^2\ 2p^6$	__ __ __ __ __
sodium	$1s^2\ 2s^2\ 2p^6\ 3s^1$	__ __ __ __ __ __ __ __ __
magnesium	$1s^2\ 2s^2\ 2p^6\ 3s^2$	__ __ __ __ __ __ __ __ __
aluminum	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$	__ __ __ __ __ __ __ __ __
silicon	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$	__ __ __ __ __ __ __ __ __
phosphorus	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$	__ __ __ __ __ __ __ __ __
sulfur	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$	__ __ __ __ __ __ __ __ __
chlorine	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$	__ __ __ __ __ __ __ __ __
argon	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	__ __ __ __ __ __ __ __ __

Complications

If you're thinking this is too easy to be true, you're right. There are a few complications as the atoms get larger. the energy levels get farther from the nucleus, the distance between the energy levels decreases. As a matter of fact, it is believed that the energy levels actually overlap. Therefore, some energy levels start filling orbitals before the previous energy level is finished filling its sublevels.

The first time this is encountered is with potassium, in which the **4s** starts to fill before the **3d** and occurs several times with the transition metals.

Example

potassium $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

$\underline{\uparrow\downarrow}\quad \underline{\uparrow\downarrow}\quad \underline{\uparrow\downarrow}\ \underline{\uparrow\downarrow}\ \underline{\uparrow\downarrow}\quad \underline{\uparrow\downarrow}\quad \underline{\uparrow\downarrow}\ \underline{\uparrow\downarrow}\ \underline{\uparrow\downarrow}\quad \underline{\uparrow}$

Complete the following orbital notations.

calcium $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

__ __ __ __ __ __ __ __ __ __

titanium $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^2$

__ __ __ __ __ __ __ __ __ __ __ __ __ __ __

The second problem has to do with a variation of Hund's Rule that takes into account the minimizing of the electron-electron repulsion. It states, the most stable arrangement of electrons is the arrangement with the maximum number of unpaired electrons. So, when the transition metals' orbitals are filling with electrons, at **d^4** and **d^9**, an electron from the **s** jumps up into the **d^5** or **d^{10}**.

Example

chromium $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^1$ $3d^5$

↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑ ↑ ↑ ↑ ↑

Complete the following orbital notation.

copper $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^1$ $3d^{10}$

___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___ ___

A Shortcut

Writing out electron configurations and orbital notations can become awkward as the atoms increase in the number of electrons. So, scientists have agreed on a type of shorthand to help make writing electron configurations and orbital notations less cumbersome.

The shorthand involves using the abbreviation of the last noble gas (placed in brackets) to indicate that all the orbitals to that point are full. Then the notation is continued as usual.

Example

nitrogen [He] $2s^2$ $2p^3$ or [He] ↑↓ ↑ ↑ ↑

chromium [Ar] $4s^1$ $3d^5$ or [Ar] ↑ ↑ ↑ ↑ ↑ ↑

Write the shortcuts for the following elements.

aluminum sulfur

Practice

Which atoms are represented by the following electron notations?

a. $1s^2$ $2s^2$ $2p^2$ **b.** $1s^2$ $2s^2$ $2p^6$ **c.** $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^3$ **d.** [Ne] $3s^2$ $3p^6$ $4s^2$

Which atoms are represented by the following orbital notations?

a. ↑↓ ↑↓ ↑↓ ↑ ↑ **b.** ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑ **c.** [Ar] ↑↓

Think It Through

- How many electrons in a stable atom?
- How many electrons in an energy level?
- How many sub energy levels in an energy level?
- How many electrons in any one orbital?
- What is an electron configuration? Arrangement?
- Can I complete an orbital notation?
- Can I complete an electron configuration?

Practice Time

Write proper name for the following rules or principles.

__________________ No two electrons in the same atom may have the same <u>four</u> quantum numbers.

__________________ Electrons will fill the lowest energy levels first.

__________________ In p, d, and f sub shells each orbital must have one electron before pairing.

Determine which elements have the following electron configurations.

__________________ $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ __________________ $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

Write the electron notation for the following. (Example: $1s^2$)

C ____

Cu ____

Write the orbital notation for the following elements. (Example: $\underline{\uparrow\downarrow}$)

S ___

Ca ___

Write the quantum numbers for the <u>hydrogen electron</u>.

n = ____ l = ____ m_l = ____ m_s = ____

"No problem can withstand the assault of sustained thinking."
--John Maxwell