Topic: 1.5 Atomic Structure and Electron Configuration

Enduring Understanding:	
SAP-1	Atoms and molecules can be identified by their electron distribution and energy

Learning Objective:	
SAP-1.A	Represent the electron configuration of an element or ions of an element using the Aufbau principle.

Essential Knowledge:	
SAP-1.A.1	The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.
SAP-1.A.2	Coulomb's law is used to calculate the force between two charged particles.
SAP-1.A.3	In atoms and ions, the electron can be thought of as being in "shells (energy levels)" and "subshells (sublevels)," as described by the electron configuration. Inner electrons are called core electrons, and outer electrons are called valence electrons. The electron configuration is explained by quantum mechanics, as delineated in the Aufbau principle and exemplified in the periodic table of the elements.
SAP-1.A.4	The relative energy required to remove an electron from different subshells of an atom or ion or from the same subshell in different atoms or ions (ionization energy) can be estimated through a qualitative application of Coulomb's law. This energy is related to the distance from the nucleus and the effective (shield) charge of the nucleus.

Equation(s):	
Force due to Coulomb's law	$F \propto \frac{q1\,q2}{r^2}$

Notes:

Atoms are made up from protons (positive), neutrons (neutral) and electrons (negative). The nucleus contains the protons and neutrons, while the electrons move around the nucleus. Most of the mass of the atom comes from the protons and neutrons, while most of the volume of an atom comes from the electrons.

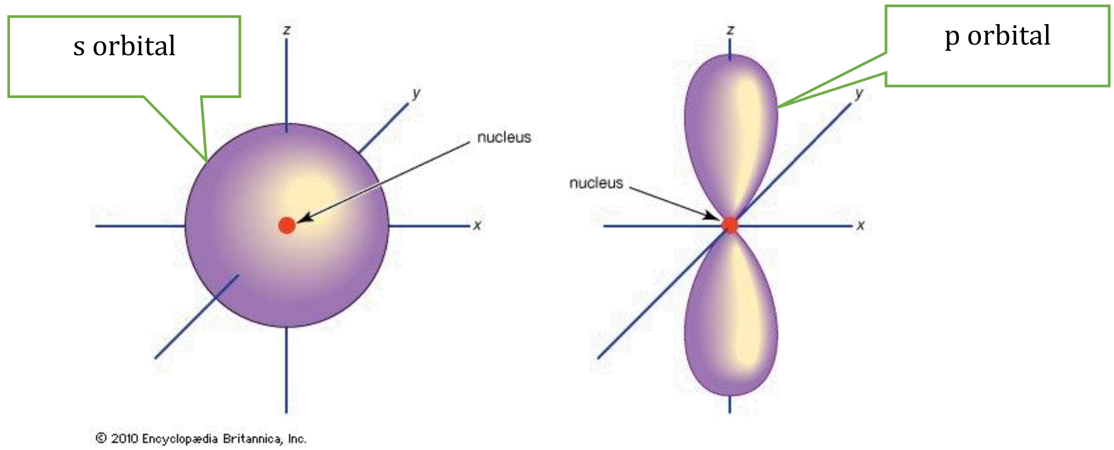
Electron Configurations are a way of describing the arrangement of electrons within an atom and are predicted by the Quantum Mechanical Model of the atom. By solving the **Schrödinger equation,** we obtain 4 quantum numbers that (n, l, m_l, m_s) which describe probable location of the electrons around the nucleus of an atom. The inner electrons are called core electrons. The outer electrons are called valence electrons.

	Name	Simple Description	Values	Notes
n	Principle quantum #	Distance from nucleus	1, 2, … n	Corresponds to the row on the periodic table for s and p. (n-1 for d, n-2 for f etc.)
l	Angular quantum #	Shape of orbital, the most likely place to find the electrons.	0, 1, 2… n-1	0 = s = o shape 1 = p = 8 shape 2 = d 3 = f
m_l	Magnetic quantum #	Orientation of orbital	-l…-1, 0, +1… l	s = 1 orientation p = 3 orientations (x, y, z) d = 5 orientations (1,2,3,4,5) f = 7 orientations (1,2,3,4,5,6,7)
m_s	Spin quantum #	Spin of electron (wave)	+1/2 , -1/2	Only two electrons fit into each orbital, often describe as "up" and "down"

THE ASSIGNMENT OF QUANTUM NUMBERS TO ELECTRONS IN SUBSHELLS OF AN ATOM WILL NOT BE ASSESSED ON THE AP EXAM.

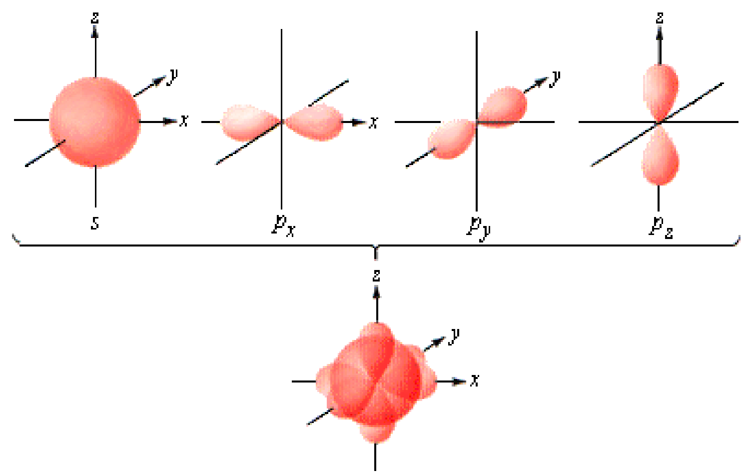
Orbitals

There are four different cloud-shapes that describe the space that the electrons are most likely to occupy, called orbitals. They are described using 4 letters, *s, p, d* and *f*. The *s* shaped cloud is a sphere around the nucleus. The *p* shaped cloud looks like two balloons tied together.



https://socratic.org/chemistry/the-electron-configuration-of-atoms/arrangement-of-electrons-in-orbitals-spd-and-f

The p orbital can be arranged in three orientations around the nucleus. This picture shows the *s* orbital and the three different *p* orbitals apart and together. Since the orbitals are electron clouds, they can overlap.

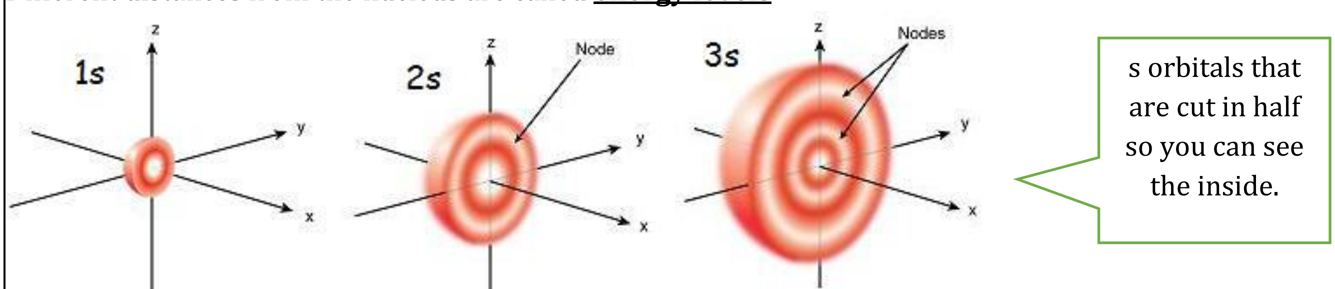


Each orbital can fit 2 electrons, each with a different spin, so the picture shows the potential location for 8 total electrons.

https://archives.library.illinois.edu/erec/University%20Archives/1505050/Rogers/Text5/Tx53/tx53.html

Energy Levels

Different distances from the nucleus are called **energy levels**.

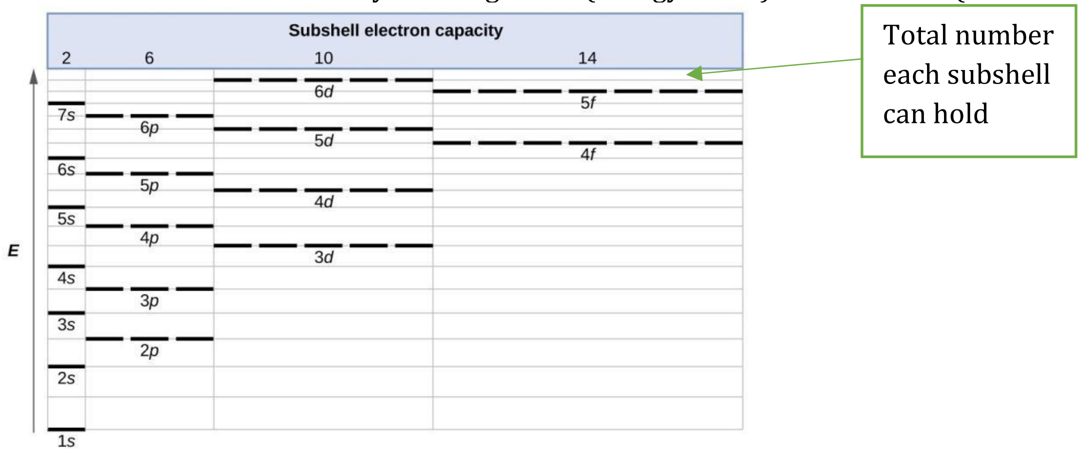


https://socratic.org/chemistry/the-electron-configuration-of-atoms/arrangement-of-electrons-in-orbitals-spd-and-f

Each energy level has different shapes possible.

Energy Level (principle quantum number)	Possible Shapes (orbitals)	Number of electrons
1	s (2 electrons)	2
2	s (2 electrons) p (6 electrons)	8
3	s (2 electrons) p (6 electrons) d (10 electrons)	18
4	s (2 electrons) p (6 electrons) d (10 electrons) f (14 electrons)	32

Electron configurations describe the model of the atom by showing shells (energy levels) and subshells (sublevels).



https://courses.lumenlearning.com/chemistryformajors/chapter/electronic-structure-of-atoms-electron-configurations/

Each dark line shows a subshell that can hold up to 2 electrons. Electrons occupy the subshells starting with the lowest energy levels first. The "lowest" energy orbitals are the closest to the nucleus. They would require the greatest energy to remove them. Remember atoms have negatively charged electrons and a positively charged nucleus.

Coulomb's Law:

This tells us that the force between charged particles is proportional to the product of the two charges and the force is inversely proportional to the squared radius between them. The force will decrease the further away the particles are. Higher charges and smaller distances between the charges result in a greater force of attraction. This explains why it takes more energy to remove electrons that are closest to the nucleus.

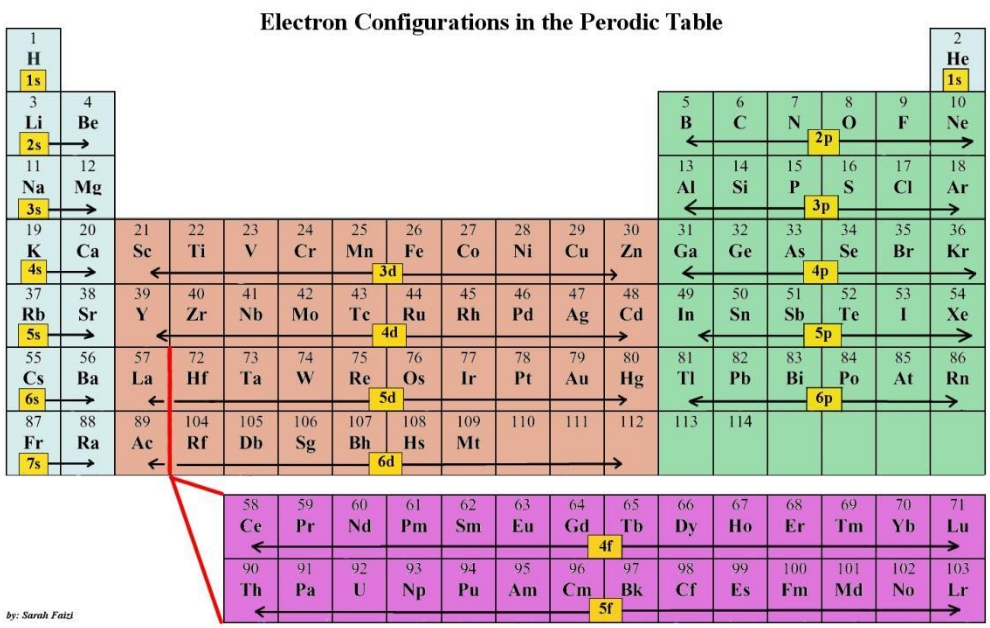
$$F \propto \frac{q1\, q2}{r^2}$$

In addition to the distance, the electrons that are on the valence shell, the outermost electrons, experience less of the nuclear pull because the electrons that are in the core of the atom block, or **shield**, the attraction of the nucleus from the valence electrons.

Rules for Electron configurations:

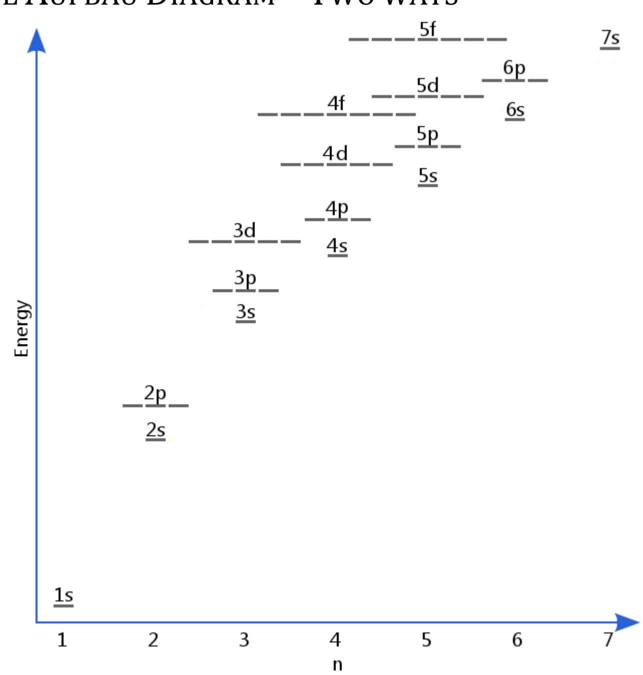
1. Aufbau principle which means “to build up,” in other words electrons are added to the lowest subshells first and build up.
2. Hund’s Rule: each subshell should have one electron before any are doubled up.
3. Pauli Exclusion Principle: no two electrons can have the same set of 4 quantum numbers.

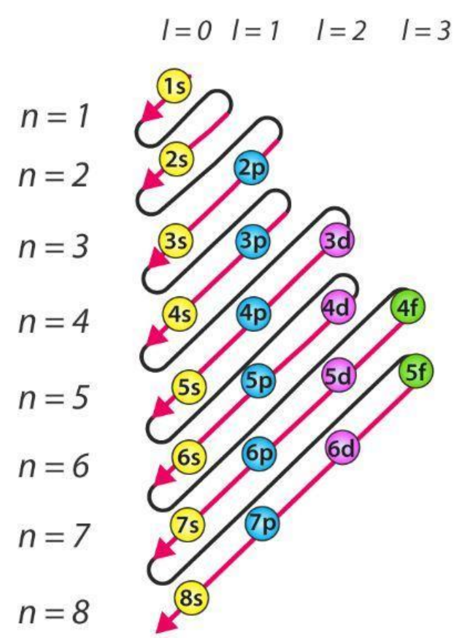
You can use the periodic table to help you with the electron configuration.



https://dashboard.dublinschools.net/lessons/?id=aaa4c826cb729596b7ca88766a73f063&v=1

The Aufbau Diagram – Two ways





https://www.chemicool.com/definition/aufbau-principle.html
https://byjus.com/chemistry/aufbau-principle/

How to write the electron configuration

Key Idea: Electrons occupy the lowest energy orbitals (closest to the nucleus) first.

Number of electrons in subshell

$$1s^2 2s^1$$

Subshells

The electron configuration for nitrogen would be as follows:

$$1s^2\ 2s^2\ 2p^3$$

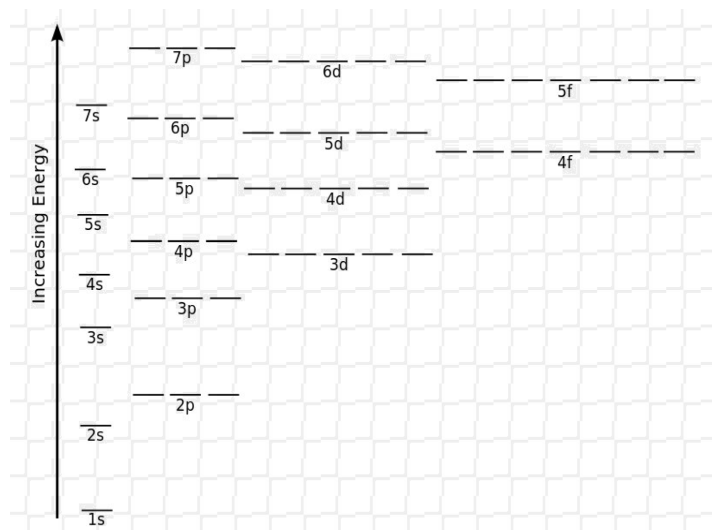
- The numbers in front (1 or 2) means the energy level or the row.
- The letters (*s* or *p)* is talking about the shape of the orbitals. (This is the shape of the electron cloud- either a sphere for *s* or the 8-shape for *p*)
- The smaller numbers at the top (the superscripts $^{2\ 2\ 3}$) tell you about the number of electrons in that type of orbital.

How to complete an Orbital Diagram

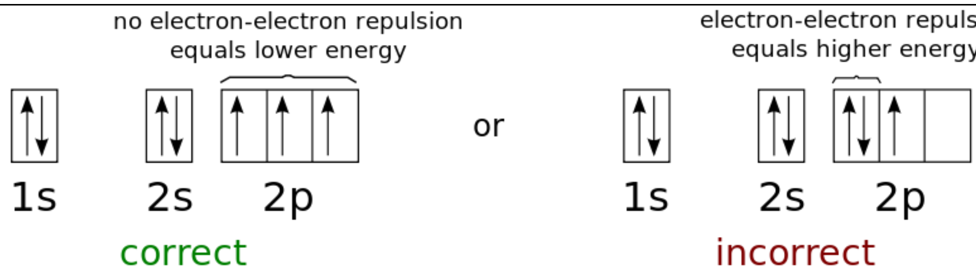
Orbital diagrams are very similar to electron configurations. However, they show the electrons as arrows and provide additional insight into the interactions between the electrons in shared orbitals.

We will start by filling in a vertical orbital diagram, but they are often simply horizontal.

1) Electrons are shown as arrows. (↑↓)
2) Always start with an UP (↑) arrow.
3) Always start by filling the lowest energy level lines first. (Pay close attention to this!)
4) Only put one or two arrows in each box, never more.
5) If you have to put two arrows in a box they have to face opposite directions, this shows they have different spins. (This is the Pauli Exclusion Principle)
6) When you have three (or more) lines in the same subshell, you put one arrow in each box before you make them share a line. (This is Hund's Rule)



You can see the linear form of an orbital diagram below. There are two ways to arrange the electrons for nitrogen, but only one follows Hund's Rule and minimizes the electron-electron repulsions.

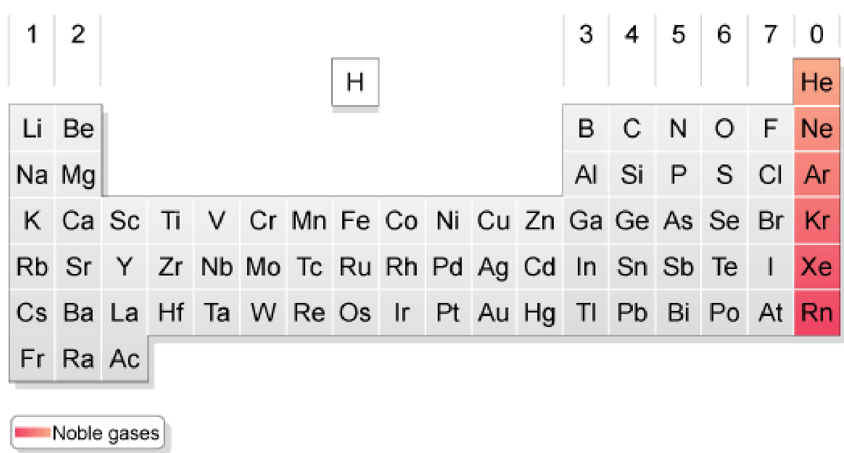


https://en.m.wikibooks.org/wiki/File:Orbital_diagram_nitrogen_-_Hund%27s_Rule.svg

NOBLE GAS/SHORT-CUT ELECTRON CONFIGURATIONS

As you can imagine, electron configurations can become very long and tedious to write. There is a shorter way to show an electron configuration, however, you must be able to write both electron configurations the long way and the short-cut way.

To write an electron configuration using the short-cut method you start by locating the noble gas preceding your element. The noble gases are the elements in group 8A on the periodic table. They are known for being unreactive. They are unreactive because they have filled valence shells. The fact that the noble gases are unreactive is why they are chosen for the noble gas short-hand electron configurations.



https://www.onlinemathlearning.com/noble-gases.html

The noble gas short hand takes the noble gas before the element and then continues on from there.

The complete electron configuration for Calcium is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$.

The short-hand noble gas configuration for Calcium would be: $[Ar]^{18}\ 4s^2$

Writing $[Ar]^{18}$ is the same as writing $1s^2 2s^2 2p^6 3s^2 3p^6$.

I DO:

Write the ground state electron configuration for Arsenic.

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

WE DO:

Write the electron configuration for Calcium ion, Ca^{2+}.

SCAN ME

YOU DO:

1. Write the ground state electron configuration for Chlorine, Cl.

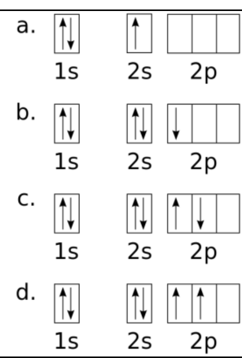
2. Write the electron configuration of fluorine ion, F^-.

3. Write the electron configuration for Aluminum ion, Al^{3+}.

4. The valence electron configuration for an unknown element is $xs^2\ xp^4$, where x is an integer. Based on your knowledge of ion formation, predict the charge for the ion that would form when this element loses or gains electrons.

5. Write the noble gas electron configuration for scandium, Sc.

6. In the diagram on the right, three of the orbital diagrams are correct and one is incorrect. Identify the elements shown for each and correct the one that is wrong.



https://commons.wikimedia.org/w/index.php?curid=16713146

7. When an electron in an atom gains sufficient energy it can move to a higher energy level (further away from the nucleus). This is called an excited state. Write an electron configuration for an excited state of sodium in which one of the 2p electrons jumps up to the 3p orbital.