Note Packet # 7

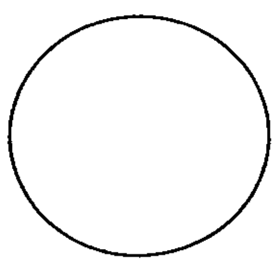
ATOMIC STRUCTURE

Atoms are the basic building blocks of matter. The smallest unit of an element is an atom. An element is composed of only one kind of atom. Obviously atoms are very small. They are so small that they can't be seen even with the most powerful light microscopes. An instrument called a scanning tunneling electron microscope is capable of viewing individual atoms. In 460 BC, the Greek philosopher, Democritus, therorized about the existence of atoms. The knowledge scientists have accumulated about atoms has resulted in the "**modern model**" of the atom. This model has evolved over a **long period of time** through the **work of many scientists**. You are responsible to know the contributions of some of these important scientists.

The following is a list of some atomic scientists, their contributions to atomic theory, and an illustration of their models.

Dalton: In the early 1800's John Dalton theorized that matter was composed of tiny indivisible spheres called atoms. A model of Dalton's atom represents atoms as spheres made of the same material.
Dalton did not consider an internal structure for atoms or the existence of subatomic particles.

A solid sphere represents Dalton's atomic model.



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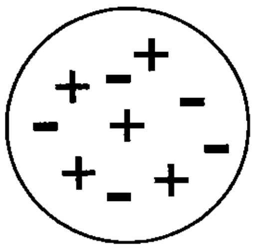
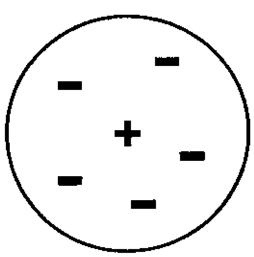
Thompson: added to atomic theory by stating that an atom consisted of negative electrons embedded in the positive sphere of the atom.



Rutherford: Rutherford's famous Gold Foil Experiment resulted in the following conclusions.

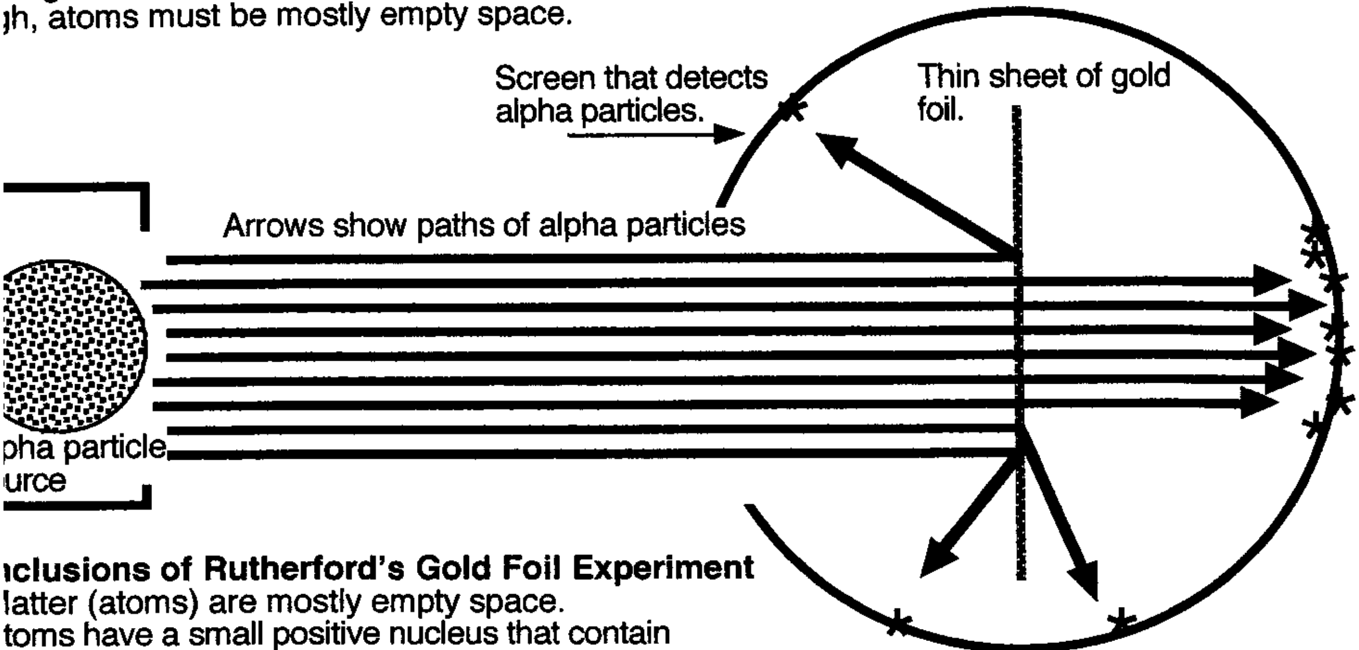
1. Matter (atoms) are mostly empty space.
2. Atoms have a small positive nucleus that contains most of the mass surrounded by negative electrons.



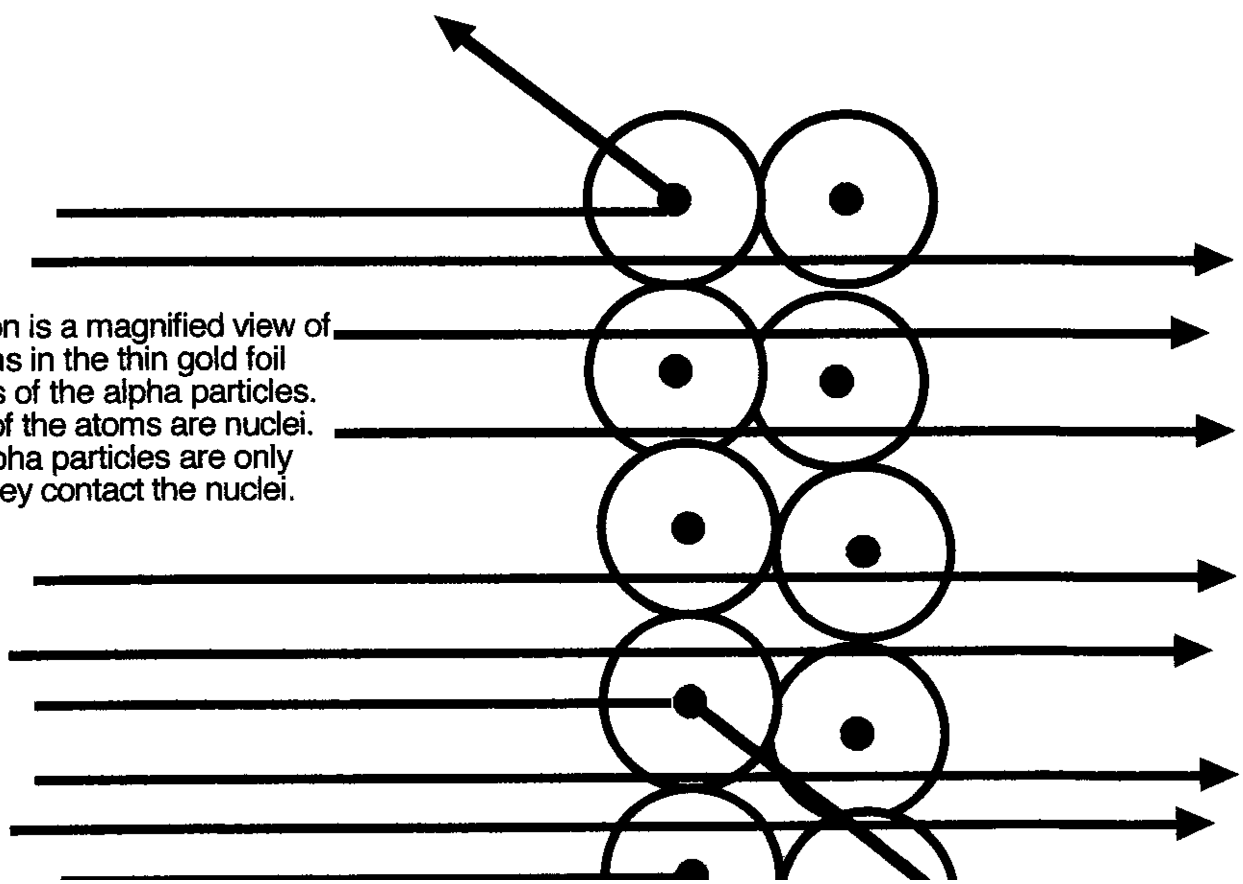
Rutherford's atomic model places a small positive nucleus at the center of the atom surrounded by negative electrons.

RUTHERFORD'S GOLD FOIL EXPERIMENT

; experiment a thin sheet of gold foil is bombarded by alpha particles. Alpha particles have a 'e charge. Nuclei have a positive charge. Like charges repel. When an alpha particle approaches ei it is deflected away. Most of the alpha particles passed straight through the gold foil. A small ntage were deflected. Rutherford concluded that since most of the alpha particles passed straight jh, atoms must be mostly empty space.



ıclusions of Rutherford's Gold Foil Experiment
latter (atoms) are mostly empty space.
toms have a small positive nucleus that contain
ı atom's mass.



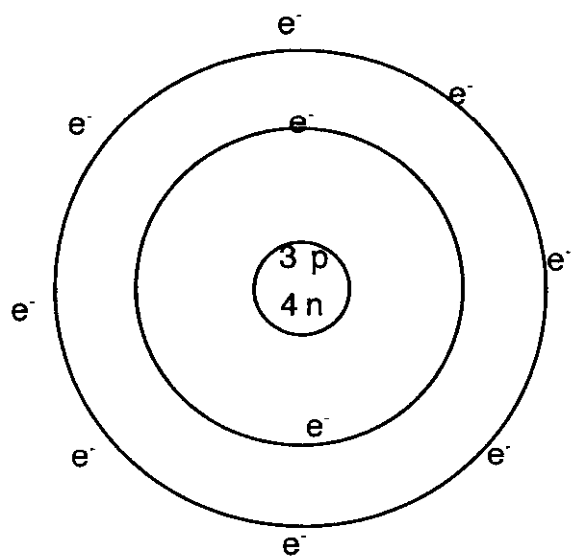
; illustration is a magnified view of gold atoms in the thin gold foil the paths of the alpha particles. centers of the atoms are nuclei. ice the alpha particles are only ected if they contact the nuclei.

Note Packet # 7

Bohr: The Bohr model of the atom places a small positive nucleus at the center of the atom surrounded by negative electrons in specific energy rings also known as levels, orbits or shells around the nucleus.

There are several important assumptions about the Bohr model.

1. The protons and neutrons are in the nucleus (small center of the atom).
2. Each electron in an atom has its own distinct amount of energy.
3. Each electron energy level can hold a maximum # of electrons.



This Bohr model shows 3 protons and 4 neutrons in the nucleus. There are 2 electrons in the first energy level and 8 electrons in the second energy level.

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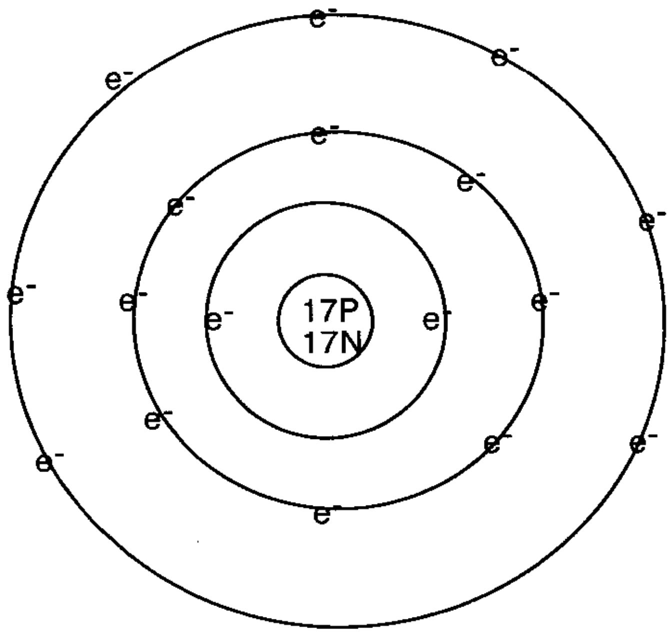
The Bohr model below shows 17 protons and 17 neutrons in the nucleus.
The electron configuration is 2-8-7

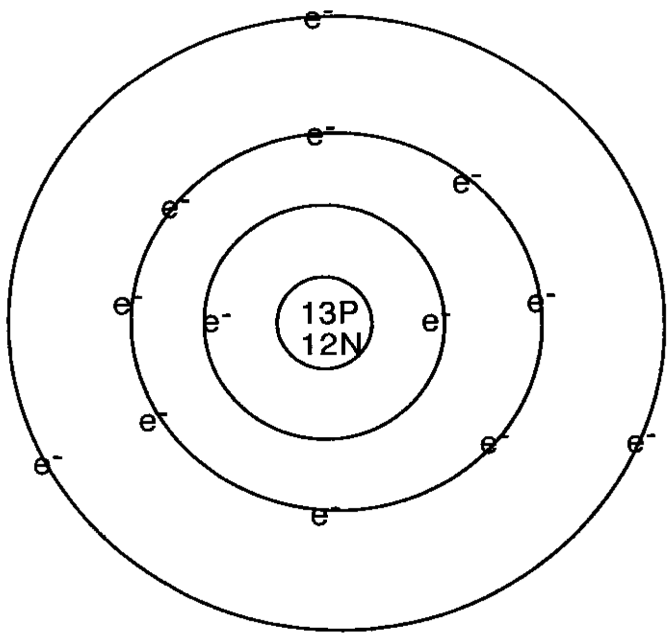


Electron Configurations are used to describe the number of electrons in each energy level. Electron configurations for any element can be found in the "Periodic Table".

Use the space below to: Draw the Bohr model of an atom with an electron configuration of 2-8-3. Include 13 protons and 14 neutrons in the nucleus.

Note Packet # 7

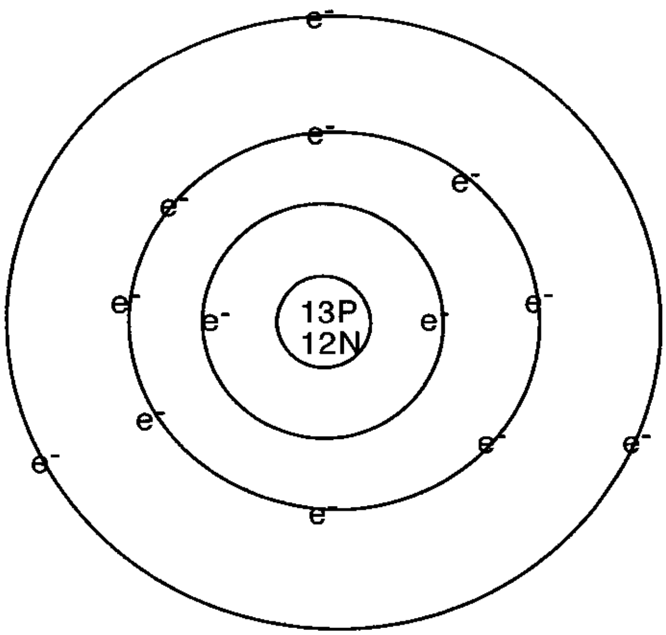
The Bohr model below shows 13 protons and 12 neutrons in the nucleus.
The electron configuration is 2-8-3.



Ground State refers to the electrons of an atom being in the lowest possible energy levels. The electron configurations in the periodic table are in the ground state.
Memory helper! **The ground is low.**

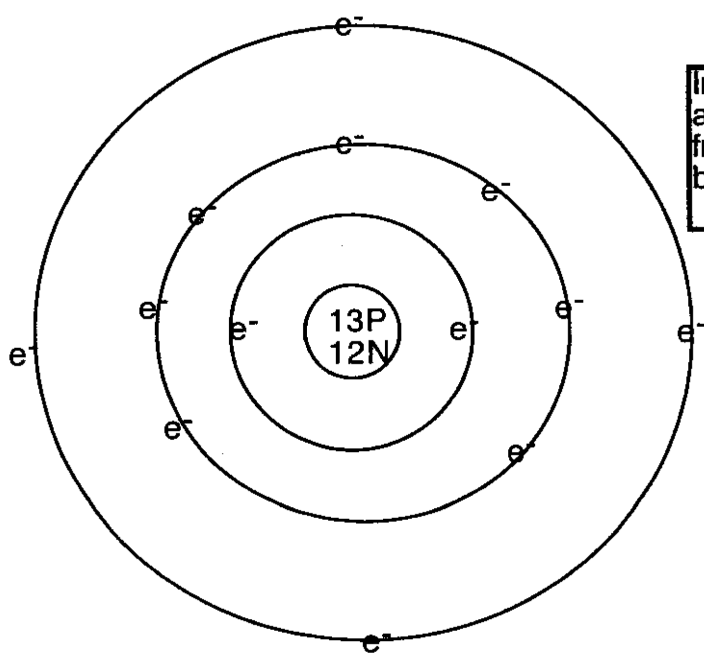
Note Packet # 7

The Bohr model below shows 13 protons and 12 neutrons in the nucleus. The electron configuration is 2-8-3. This is the **ground state**. Electrons are in the lowest levels.



This page compares the Bohr Model of a magnesium atom in the Ground State vs. the Excited State

The Bohr model below still shows 13 protons and 12 neutrons in the nucleus. An electron from the 2nd level absorbed energy and jumped to the 3rd level. The electron configuration for this **excited state** is 2-7-4.



Important! Atoms keep the same amount of electrons when going from ground to excited state and back. Electrons just change levels.

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Valence Electrons are the electrons found in the outermost energy level. There can only be a **maximum of 8 valence electrons**. This means there can never be more than 8 electrons in the outer ring.Valence electrons are responsible for the chemical behavior of atoms. This will be important in the topic of "Chemical bonding".
Ex: The electron configuration 2-8-2 has 2 valence electrons.

How many valence electrons are in the configuration 2-8-8? ______________

Write the electron configuration for each of the following elements and determine the number of valence electrons of the following elements in the ground state.

	electron configuration	# of valence electrons
1) Li		
2) Ne		
3) Ar		
4) Al		
5) Fe		
6) C		

Each energy level can hold a maximum # of electrons. Remember the valence level (outermost level can only hold a maximum of 8 electrons).

The formula $\mathbf{2n^2}$ is used to calculate the maximum # of electrons in an energy level.
n = the principle energy level #.

Examples:

Determine the maximum # of electrons in each of the following energy levels.

Level # 1 $2(1^2) = 2$
Level # 2 $2(2^2) = 8$
Level # 3 $2(3^2) = 18$

Determine the maximum # of electrons in the following energy levels.

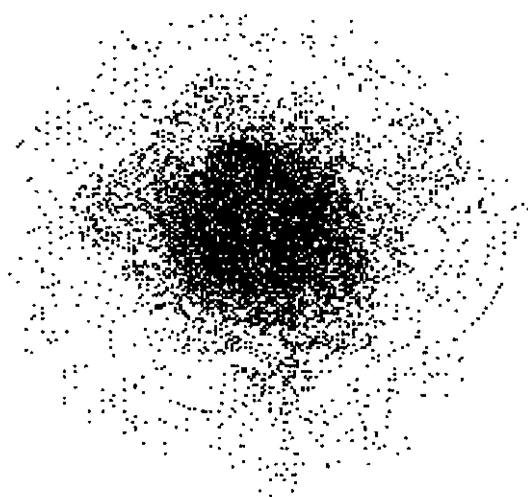
Level # 4

Level # 5

Note Packet # 7

Modern model: also known as the **wave mechanical** or **electron cloud** places protons and neutrons in the small central nucleus. Electrons are found in **orbitals. Orbitals** are defined as **probable locations** where electrons may be found. Think of this ! Orbital rythms with probable, rythms with wave mechanical.

In the modern model, the tiny nucleus can not be seen under the "electron cloud".
The electron cloud is the **orbital**. The cloud consists of locations an electron can be found. Each dot represents a possible electron location The densest part of the cloud is where electrons can most often be found. The faint part of the cloud is where electrons are found less often.



The modern model of the atom has evolved over a long period of time through the work of many scientists.

Note Packet # 7

Subatomic particles: Even though every element has its own unique atom, all atoms are composed of the same subatomic particles. The subatomic particles are protons, neutrons, and electrons.
You need to know the mass, charge, and location of the subatomic particles.
Mass of subatomic particles is measured in atomic mass units (amu). An amu is very small the mass of 1 amu is 1.7×10^{-24} gram. An **amu is based on 1/12 of the mass of a carbon-12 atom**.
The charge of subatomic particles is designated as positive (+), negative (-), or no charge (0), also called neutral.

Subatomic particle	**Mass**	**Location**	**Charge**
Proton	**1 amu**	**Nucleus**	**+1**
Neutron	**1 amu**	**Nucleus**	**0 (neutral) no charge**
Electron	**insignificant or** $\frac{1}{1836amu}$	**Outside the nucleus**	**-1**

The mass of an atom is determined by its numbers of protons and neutrons. Electrons are not considered when determining atomic mass.
The mass of an atom is calculated by adding the number of neutrons and the number of protons.
Mass = protons + neutrons. **Protons + Neutrons = Mass**
If any 2 of the 3 are known the other can be calculated.
An atom with 11 protons and 12 neutrons has a mass of 23 amu.
An atom with 9 protons and 10 neutrons has a mass of 19 amu.
Example: Calculate the mass of an atom with 17 protons and 18 neutrons.
17 + 18 = 35 amu
Don't forget! Electrons are not considered when determining mass.
Example: Calculate the mass of an atom with 20 protons, 22 neutrons, and 20 electrons.
20 + 22 = 42 amu
Example: If an atom with a mass of 37 contains 17 protons calculate the number of neutrons.
37 - 17 = 20 neutrons
Example: If an atom has a mass of 50 and contains 26 neutrons calculate the number of protons. 50 - 26 = 24
Try these examples.
Determine the mass of an atom if it contains;
a) 12 protons and 12 neutrons.

b) 16 protons and 18 neutrons.

c) 3 protons and 4 neutrons.

d) Determine the number of neutrons if an atom has a mass of 30 and 14 protons

e) Determine the number of protons if an atom has a mass of 61 and 33 neutrons

Note Packet # 7

All atoms of an element are assigned an atomic number. An atom's atomic number is the determined by its number of protons. The number of protons in an atom determines which element it is.

An atom with 1 proton has an atomic number of 1. An atom with an atomic number of 85 has 85 protons. The number of protons determines the element.

The **Periodic Table of the Elements** lists the atomic numbers of each element.

All atoms are neutral.

All atoms always have an equal number of protons and electrons. Protons are positive and electrons are negative. This results in all atoms being neutral.

If something is referred to as an atom it is neutral!

If you know the number of electrons in an **atom** you know the number of protons.

If you know the number of protons in an **atom** you know the number of electrons.

Ions : The nucleus (protons and neutrons) of an atom is unchanged by chemical processes, but atoms can easily gain or lose electrons. If electrons are added to or removed from a neutral atom, a charged particle called an **ion** is formed.

If an atom gains or loses 1 or more electrons it is no longer neutral and can not be considered an atom any more. It is an ion.

A positive ion is called a **cation**. A negative ion is called an **anion**.

The **charge of an ion** is determined by algebraically adding the + protons to the - electrons.

Example: What is the charge on an ion that contains 9 protons and 10 electrons?

To solve:	9 protons produce a	+ 9 charge
	10 electrons produce a	<u>-10 charge</u>
		-1 is the charge on the ion

Example: What is the charge on an ion that contains 15 protons and 18 electrons?

To solve:	15 protons produce a	+ 15 charge
	18 electrons produce a	<u>-18 charge</u>
		-3 is the charge on the ion

Example: What is the charge on an ion that contains 20 protons and 18 electrons?

To solve:	20 protons produce a	+ 20 charge
	18 electrons produce a	<u>-18 charge</u>
		+ 2 is the charge on the ion

Protons - electrons = charge   p - e = charge

Solve the following:

1) What is the charge on an ion that contains 38 protons and 36 electrons?

2) What is the charge on an ion that contains 53 protons and 54 electrons?

3) What is the charge on an ion that contains 16 protons and 18 electrons?

Note Packet # 7

Species: is a term used to describe a "thing". The thing may be an atom or an ion. If you know the number of protons, neutrons, and electrons a species contains you can determine its atomic number, mass, if it is an atom or ion, and its charge.

Complete the following table for each species.

Protons	Neutrons	Mass	Electrons	Atom or Ion	Charge
11	12		10		
35		80	36		
	118	197	78		
4	5			atom	
1		1			0
8	8				-2
	7	14			-3
26	28				+3

Nuclear Charge refers to the charge of an atom's nucleus. All nuclei are positive. The number of protons (atomic number) determines the nuclear charge.

Ex: The nuclear charge of a carbon atom is + 6. Why? Because carbon's atomic # is 6. All carbon atoms have 6 protons. The number of protons determines the nuclear charge.

Determine the nuclear charge of the following atoms.

a) Boron

b) Calcium

c) Magnesium

d) Yttrium

e) Radon

f) Hydrogen

g) Argon

Note Packet # 7

Atoms of the same element must always have the same number of protons. However; the number of neutrons in atoms of the same element may be different.

Atoms that have the same number of protons but a different number of neutrons are called **isotopes**.

Isotopic notation is a system that indicates both the # of protons (atomic number) and the mass # of an atom. When an isotope is represented by its symbol, Atomic #, and mass # it is often referred to as a **nuclide**.

The top number is the mass # (protons + neutrons). → $^{3}_{1}H$

The bottom number is the number of protons (atomic #). →

$^{14}_{6}C$ ← **These are isotopes of each other.** → $^{12}_{6}C$

When naming isotopes, state the name of the element followed by the mass #.

Ex: $^{235}_{92}U$ is called Uranium-235.

Ex: $^{14}_{6}C$ is called Carbon-14.

Name the following isotopes. Use the reference tables if you do not know the name of the element.

a) $^{7}_{3}Li$

b) $^{141}_{56}Ba$

c) $^{91}_{36}Kr$

d) $^{90}_{38}Sr$

e) $^{16}_{7}N$

f) $^{43}_{21}Sc$

Note Packet # 7

Average atomic mass The mass on the periodic table for each element is **the weighted average of the elements naturally occuring isotopes.** All elements have atoms that exist as different isotopes. Since different isotopes have different masses an average mass can be calculated.

You will need to be able to calculate average atomic mass.

To calculate average atomic mass.

1) Convert the percentage of each isotope to a decimal by dividing by 100 (move the decimal 2 spaces to the left).
2) Multiply the decimal of each isotope by its mass.
3) Add the results together.

Ex: What is the average atomic mass of an element if 30% percent of its isotopes have a mass of 42 and 70% have a mass of 45.

To solve:

1) convert 30% to .30 convert 70% to .70

2) .30 X 42 = 12.60
   .70 X 45 = 31.50

3) 12.60
   + 31.50
   44.1 average atomic mass

Calculate the average atomic mass for the following.

a) An element with 55% of its isotopes have a mass of 78 and 45% of the isotopes have a mass of 83.

b) An element with 62% of its isotopes with a mass of 18 and 38% of the isotopes with a mass of 23.

You will also have to determine the most abundant isotope from an average atomic mass.

This is simple to do. The isotope with the mass that is the closest to the average atomic mass is the most abundant.

Ex: The average atomic mass of an element is 35.5 . Its isotopes have masses of 37, 35 and 34. The most abundant isotope has a mass of 35.

Note Packet # 7

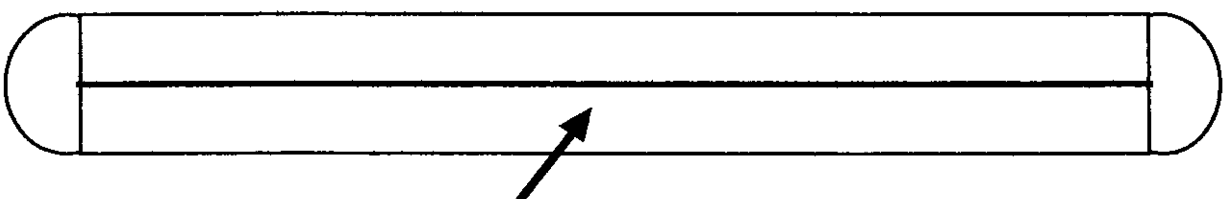
The Behavior of Charges

You have probably heard the expression "opposites attract". Electric charges do just that. Opposites attract and like repel. Electric charges are similar to magnets. Opposite poles of magnets attract. Like poles of magnets repel.

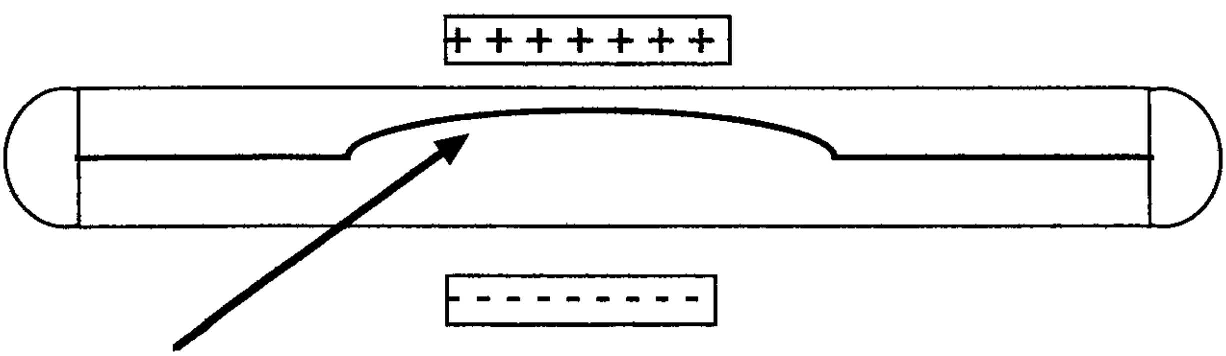
Paths of electrically charged particles can be deflected (changed) by electric or magnetic fields.

A common experiment uses electric charges to deflect a stream of electrons in a vacuum tube.
Remember! Electrons have a - charge.

When no external charge is present electrons travel in a straight line.



Straight stream of electrons



Stream of electrons attracted to the + charge and repelled by the negative charge.

Note Packet # 7

Ground State as mentioned earlier ground state refers to an atom's electrons being in the lowest possible energy levels (as found in the periodic table).
Excited State is when one or more of an atom's electrons jumps to a higher than normal level. This jump is called a **quantum leap**. Electrons can only exist on a ring or level! They can not exist in-between levels.
There is only one ground state electron configuration for each element. However; there are many possible excited state electron configurations for each element.
***Remember, there is a maximum # of electrons that can occupy a principle energy level.** $2n^2$

How does an electron jump to a higher level? It does so by absorbing a specific amount of energy. The energy may be from heat, electricity, or from another source. Electrons in higher than normal levels quickly go back down to their normal low levels. When electrons return to the low levels, they release energy in the form of colored light. Each electron in an atom absorbs and releases an exact amount of energy to move up and back down a level. This amount of energy corresponds to a specific wavelength of light.
A light's wavelenght determines its color.
We as humans precieve color based on the wavelength of the light that enters our eyes.

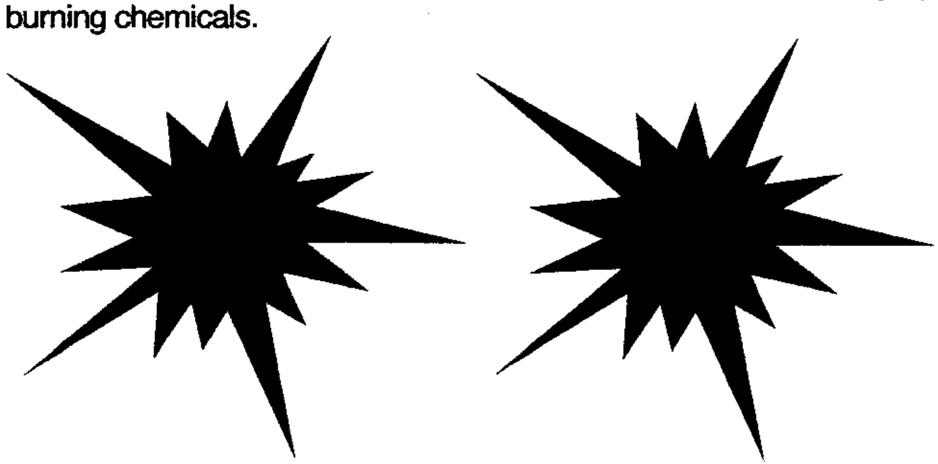
Important!

When electrons **absorb** energy they move to **higher** levels!
When electrons **release** energy they move to **lower** levels!

Electrons **releasing energy** as they move to lower levels **can be seen** since the energy they give off is in the form of **colored light**.

Electrons **absorbing energy** and moving to higher levels **can't be seen** since no energy (no light) is given off.

The amount of energy and wavelength of light given off by electrons as they move back to lower levels in an atom is unique (special) for each type of atom. This results in unique colors for each type of atom. Since every element has its own type of atom the color of light emitted (given off) is different.
The colors of fireworks are the result of different chemical elements being added to other hot burning chemicals.



Note Packet # 7

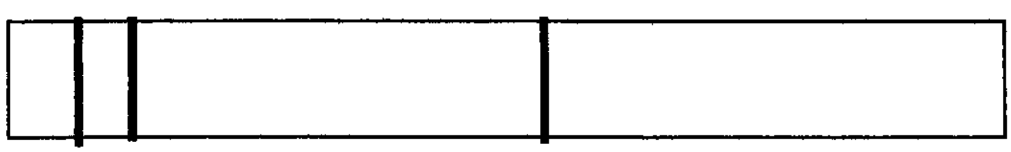
Flame Test

Flame Test
A flame test involves heating atoms to a high temperature using a flame. The heat energy is absorbed by electrons causing them to go from their lowest (ground state) levels to higher levels (excited state). This leap up is not visible.
Since electrons quickly return to lower levels they release energy in the form of colored light. This particular colored light can be used to identify an unknown element.

Describe how colors are produced in a flame test.

Spectroscopy

Spectroscopy
A possible problem with using a flame test to identify an unknown element is that the human eye may have difficulty noticing the slight difference between similar colors. Shades of orange, yellow, red, and pink often look very similar. A **spectroscope** is an instrument similar to a prism. It separates light into individual colors according to wavelength. Spectroscopy is a more reliable method for identifying an unknown element. When the light from excited atoms is separated by a spectroscope a series of colored bands results. This series of colored bands is called a **bright line spectrum.** Every element has its own particular bright line spectrum. An unknown element can be identified by comparing its spectrum to a series of knowns. Scientists know a lot about stars by examining their light with sensitive spectroscopes.
Real bright line spectrums are in color.
You will need to know how to interpret black and white representations of bright line spectrums to identify an unknown element.



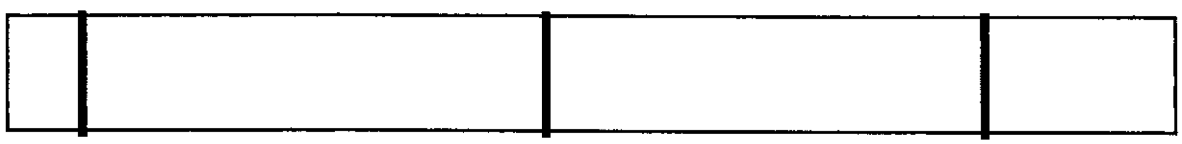
The solid lines represent the location of bands of colored light as seen through a spectroscope. The location of the bands are unique for every element.

Note Packet # 7

Element A

Element B

Element C



Unknown Element

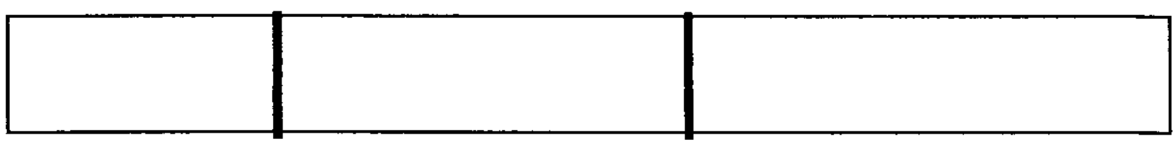
Comparing the unknown element to the known elements tells us that the unknown element is Element A.

If you have difficulty lining up the lines use a ruler.

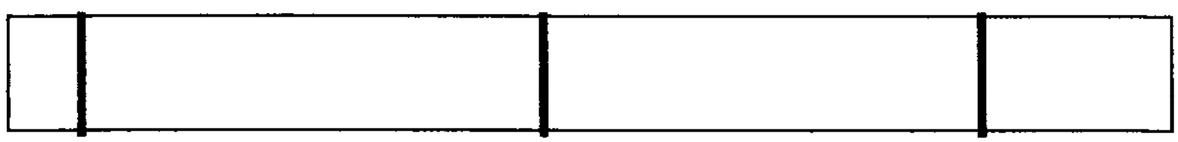
Note Packet # 7

Element A

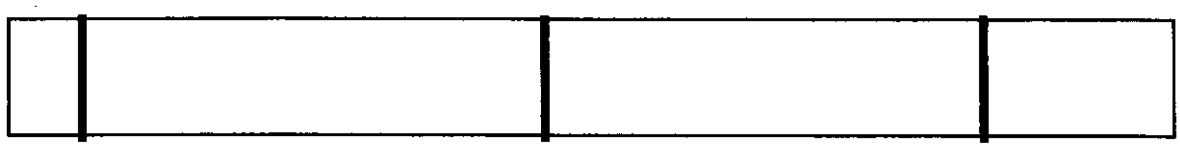
Element B



Element C



Unknown Element



Comparing the unknown element to the known elements tells us that the unknown element is Element C.

If you have difficulty lining up the lines use a ruler.

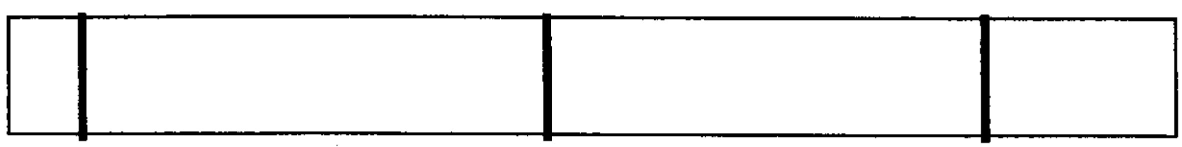
Note Packet # 7

For this example the unknown contains 2 different elements.

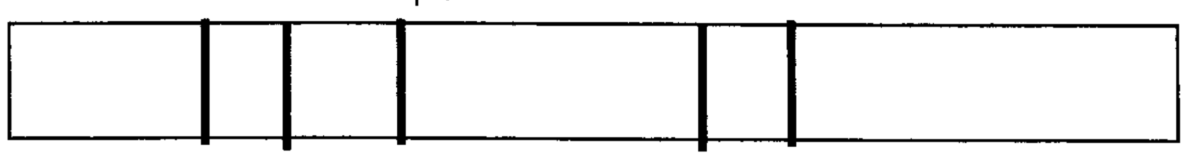
Element A

Element B

Element C



Unknown Sample

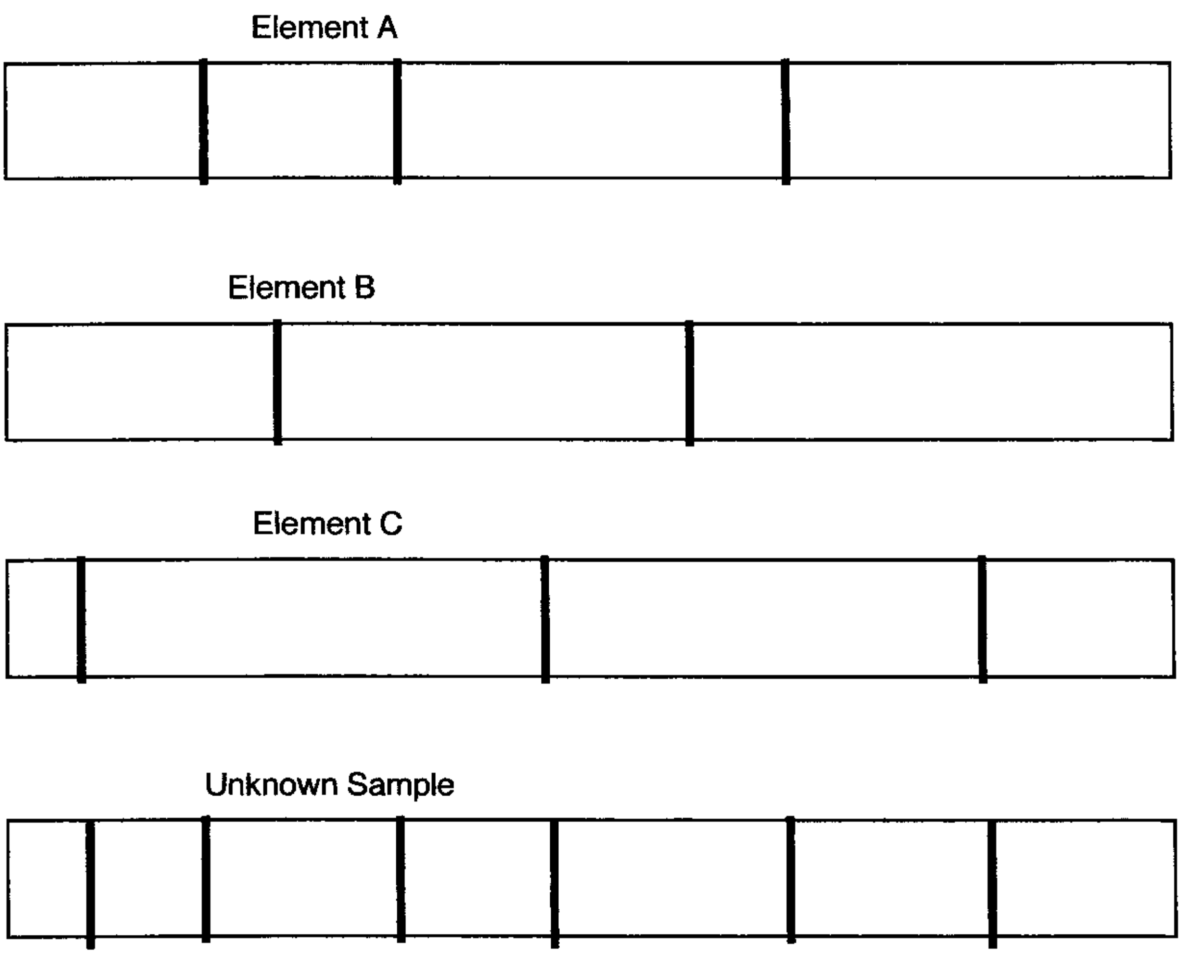


Comparing the unknown element to the known elements tells us that the unknown sample contains both Element A and Element B.

If you have difficulty lining up the lines use a ruler.

Note Packet # 7

Determine the elements in the unknown.



If you have difficulty lining up the lines use a ruler.