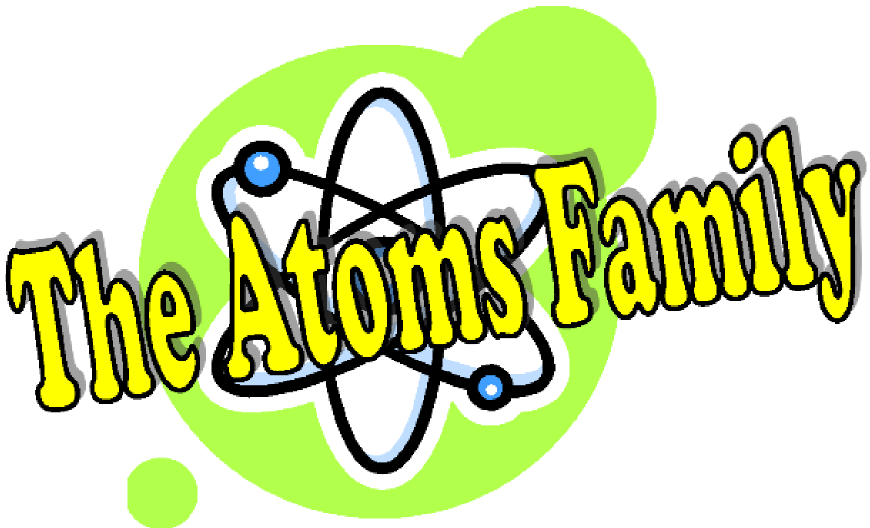
Name:________________Period:_________Date:______
General Chemistry Unit 3 Atomic Theory

Unit Objectives:

- Understand that the modern model of the atom has evolved over a long period of time through the work of many scientists
- Discuss the evolution of the atomic model
- Relate experimental evidence to models of the atom
- Identify the subatomic particles of an atom (electron, proton, and neutron)
- Know the properties (mass, location, and charge) of subatomic particles
- Determine the number of protons, electrons, and neutrons in a neutral atom and an ion
- Calculate the mass number and average atomic weight of an atom
- Differentiate between an anion and a cation
- Identify what element the amu unit is derived from
- Distinguish between ground and excited state
- Identify and define isotopes
- Write electron configurations
- Generate Bohr diagrams
- Differentiate between kernel and valence electrons
- Draw Lewis Dot Diagrams for an element or an ion

<u>Define the following vocabulary:</u>

Allotrope	Anion
Atom	Atomic Mass
Atomic Mass unit (a.m.u.)	Atomic number
Bohr model	Cation
Compound	Electron
Electron Configuration	Element
Excited state	Ground state
Ion	Isotope
Lewis Dot Diagram	Mass number
Neutron	Nuclear Charge
Nucleons	Nucleus
Orbital	Proton
Valence electron(s)	Wave-mechanical model



The Atoms Family Song

1st Verse:

They're tiny and they're teeny,
Much smaller than a beany,
They never can be seeny,
The Atoms Family.
Chorus

2nd Verse:

Together they make gases,
And liquids like molasses,
And all the solid masses,
The Atoms Family
Chorus

3rd Verse:

Neutrons can be found,
Where protons hang around;
Electrons they surround
The Atoms Family.
Chorus

Chorus:

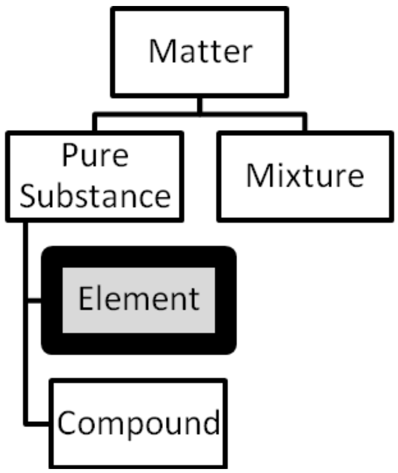
They are so small.
(Snap, snap)
They're round like a ball.
(Snap, snap)
They make up the air.
They're everywhere.
Can't see them at all.
(Snap, snap)

Lesson 1: Concept of an Atom **Date:______**

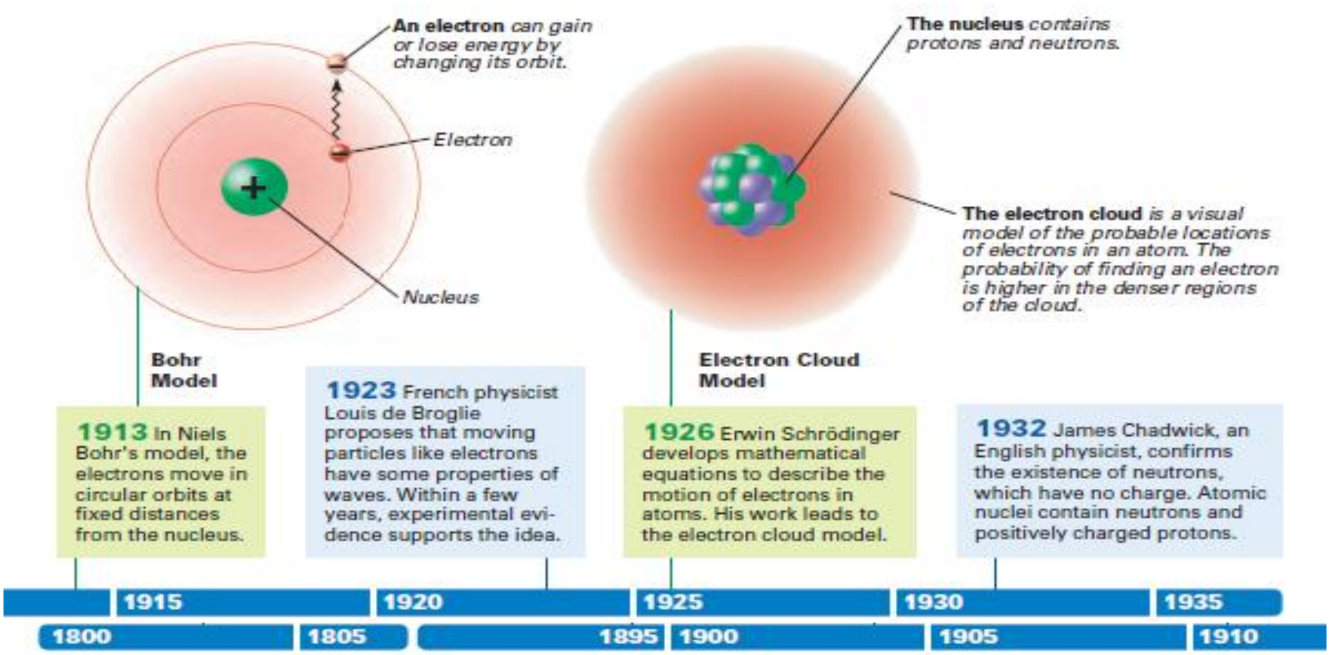
Do Now: Draw a picture of an atom. Describe the parts of an atom.

____
____
____

Often in science, we are only aware of a certain amount of information at a time. As we learn new facts, we can edit our current knowledge and develop deeper understandings of what we are studying. This is why science is often changing... we are constantly learning new things! We learned in Unit 1 that the smallest unit of matter is called an atom. An atom is a type of pure substance. Atoms are not the same as elements. Atoms are the particles that make up elements. An element can be made of many atoms.



The concept of an atom is one that has evolved over time. Many different scientists have contributed to our understanding of the atom by doing various experiments to form their theory or view of the atom. Each person relied heavily on the scientist before them and they either supported or refuted the theory that existed at the time.



Atomic models are theories that describe what the physical properties of an atom are (how it looks structurally). These physical properties will help determine the chemical proper ties of an atom (how it behaves).

Our current model of the atom, the electron cloud model, is based on all the ones that came before it.

Check your understanding:

Based on the diagrams, explain how the atomic model has evolved in complexity over time.

____
____
____
____
____
____
____
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Lesson 2: The Atom – Background & History **Date:________**

Do Now: Read the cartoon. What is the relationship between the atom and all living things?

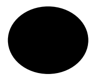
____
____
____
____

Atom: smallest particle of an element that retains its properties.

1. The Ancient Greeks Propose a Good Idea - Democritus:

a. He was a Greek smart guy (a philosopher, a thinker) who suggested an indivisible form of matter.
b. He did no "science." Testing of a good idea did not occur.

SKETCH:



2. Rediscovering a Good Idea: Dalton and Atoms (1766-1844):

a. He proposed that all elements are composed of a "smallest particle" that could not be further subdivided.
b. He suggested that all atoms of the same element are identical.
c. He noted that atoms of different elements can combine with each other in simple, whole number ratios to form compounds. (Some simple compounds were known about by the early 1800's. Among the first was ammonia – NH_3)
d. It was called the "cannonball model" since he considered the atom a solid sphere.
e. Recall particle diagrams / Conservation of Mass:

*Chemical reactions (aka "chemical changes") occur when atoms/molecules are: rearranged, joined, or separated. **Note that the atoms themselves remain unchanged!***

Question: What are the similarities/differences between Democritus and Dalton's theory/model of the atom?

3. Discovery of Subatomic Particles…Dalton's Undoing…

a. Starting in the late 1800's, particles smaller than atoms were being detected in experiments.
b. Eventually, this collection of particles was referred to as "sub-atomic" (smaller than atomic) particles.
c. These particles are called ***electrons, protons and neutrons*** today.

Question: How does the discovery of these particles refute Dalton's theory of the atom?

Check your understanding:

Directions: Using the words below fill in the blanks

cannonball Dalton compounds identical atom founder indivisible properties and masses

___________ was known as the ______________ of the atomic theory.
Dalton invented the word ___________ as the basic unit of matter which were considered to be ____________________.Dalton also claimed that all atoms of a given element are _____________. He also discovered that atoms of different elements have different __________________________________. He found that combining atoms of different elements formed ____________________. His theory was referred to as the _________________ model (it looked like a simple sphere)

Reading: Birth of Elements

The Birth of the Elements by David Thielk

As you begin your study of chemistry, the task of learning about the millions of different chemical substances that make up your world seems hopelessly complicated. But you've probably already been surprised to find that all of them are made from only a few more than 100 different chemical elements combining in an infinite variety of ways. Even your own body—complex as it is—comprises only a few dozen of these known elements. The fact that all matter is made from the combinations and recombinations of this short list of elements suggests a very basic question: Where did the elements that make up our bodies and all of our surroundings come from? Scientists believe they have the answer, and it shines with startling beauty: "We are made of stardust."

The origins of hydrogen and helium

Astrochemists estimate that hydrogen makes up about 75% and helium about 25% of all of the matter in the universe today. Although many of the remaining elements seem abundant from our earthly point of view, they exist in only trace amounts in the universe as a whole. Where did all of this hydrogen and helium originate? Scientists conclude that approximately 16 billion years ago, the matter of the entire universe was contained within a tiny but incredibly dense sphere. The explosion of this tiny sphere—the Big Bang—marked the moment when the universe began and both space and time came into existence. Some remarkable things happened in those first few moments of time. The explosion occurred a mere 10−43 seconds after the Big Bang began. During the first second or so, highly energetic photons collided and converted their energy into mass, creating protons, neutrons, and electrons—components of future atoms. Within these first seconds, the temperature of the universe dropped from a high of about 1032 K down to about 1010 K. In another three minutes, the universe had cooled to 109 K or about a billion Kelvin—the temperature at which protons and neutrons can combine to form the nuclei of a few of the elements, like helium. And then the action slowed down. In fact, as radiation and matter continued to spread out, temperatures dropped even further, and nucleosynthesis eventually stopped. At this stage, some nuclei existed, but no atoms. It was still too hot. It took another 300,000 years for temperatures to cool to about 3000 K—the temperature at which electrons, the currency of chemical reactions, could combine with nuclei. Atoms were born and molecules soon followed.

Where do stars come from?

Stars are born in Giant Molecular Clouds (GMCs)—often located in the arms of spiral galaxies. Space isn't empty. It contains vast amounts of gaseous matter. The first GMCs were almost entirely hydrogen and helium. Today, they contain trace quantities of heavier elements as well. Inside a GMC, gravity acts to draw the gas molecules together. Just as a ball released from your hand loses potential energy and gains kinetic energy as it falls, the condensing gas molecules in the GMC convert gravitational potential energy into kinetic energy in the form of heat. A star is born when the core temperature of a GMC reaches about 10 million Kelvin. At this point, a new kind of nucleosynthesis begins. The entire process involves several steps and can undergo a variety of stages depending on the presence of small amounts of heavier elements such as carbon and nitrogen. But by far, the most important events that accompany the birth of a star involve the net conversion of hydrogen nuclei into helium nuclei. Why does this hydrogen to helium conversion release so much energy? Einstein's famous equation—E = mc2—holds the key. In simple terms, this equation says that mass and energy can be converted into each other. Accurate measurements of the masses of the reacting hydrogen nuclei and the resulting helium nuclei plus a few subatomic particles show that the product mass of this nuclear reaction is only slightly less than that of the initial hydrogen nuclei. But that's where the letter c becomes important. Since c, the velocity of light, is a very large number (3 × 106 m/s) and the square of c is even larger, a very small amount of mass releases an enormous amount of energy upon conversion. Our own sun pours out energy at a rate of about 3.9 × 1026 Joules/second. To produce this much energy, about 700 million tons of hydrogen are converted to about 695,000,000 tons of helium every second. This means that our sun is converting mass to energy at the rate of about 5 million tons every second! Once fusion begins in the core of the young star, the pressure (outward) from the fusion reaction balances the force of gravity (inward), and a star enters a relatively stable period that constitutes the main part of its life. Our own sun reached this point about 5 billion years ago. In another 5 billion years or so, the hydrogen at the core will run out. When hydrogen fusion stops, gravity will once again prevail. The core will collapse and generate more heat. As the temperature increases, a new round of nucleosynthesis will begin as helium atoms begin to fuse together. There are several fusion pathways that can occur in a star, depending on its mass, but the basic process is this. When the hydrogen in the core of the star is used up, fusion of hydrogen nuclei into helium nuclei ceases. Without enough outward pressure to counteract the force of gravity, the star begins to collapse. But all of this collapsing causes the helium core to heat up. Then the hydrogen that was once outside the core is drawn inward, compressed, and heated enough so that fusion of hydrogen into helium begins again. As the core collapses, its temperature eventually becomes hot enough (about 100 million K) to trigger the fusion of helium into heavier elements. At this stage of its life, a star consists of two shells—an outer one in which hydrogen is fusing into helium, and an inner one in which helium is fusing into heavier elements such as carbon and oxygen. Eventually, there is no more helium fuel in the core. If the star is massive enough, another round of collapsing and core reigniting takes place producing three distinct layers—an outer layer where hydrogen is fusing into helium, a middle layer where helium is fusing into heavier elements, and an inner core where heavier oxygen and carbon are fusing. This innermost fusing yields a variety of heavier elements, including neon and magnesium. The pattern of using up the core fuel, collapsing, and reigniting can occur several times, producing a variety of isotopes of the heavier elements— silicon, phosphorus, sulfur, calcium, and others. But even stars cannot produce nuclei with atomic numbers greater than that of iron. Iron represents the element with the most *stable* nucleus—the nucleus of lowest energy. No additional energy can be released by fusing iron into heavier elements. If stellar synthesis ceases with the formation of iron, where do the heaviest elements come from?

The heavy elements

Although scientists understand the formation of lighter elements better than the formation of heavier elements, they are confident about the sources. Although some of the heavy elements originate within steadily burning stars, most of our heavy elements form as a result of a spectacular astronomical event called a *supernova*. The majority of stars fade away as white dwarfs. But after a very massive star spends its fuel in the series of nuclear fusion cycles already described, its core begins to turn to iron. Iron, the element with the most stable nucleus, cannot undergo fusion. When the iron core becomes massive enough, there is no longer enough fusion occurring to produce the outward force necessary to counteract gravity. At this point, the core of the star collapses under its own weight. This collapse crushes the nuclei and free electrons, transforming the core into one made entirely of neutrons. Even though it took the iron core of this star millions of years to form, in a single instant, it transforms entirely to neutrons. With a diameter of only 20 km or so, the neutron core is small—but unbelievably dense! A mere teaspoon of this core material would weigh about 50 billion earthly tons. And then the explosion! The supernova detonation occurs when the material of the outer layers of the star falls rapidly toward the neutron core. The core—no longer collapsing— is now a hard surface, off of which the outer material bounces. The result is a shock wave that propagates outward, blasting the outer core of matter so violently that nuclear particles are forced together, creating elements heavier than iron. These heavy elements blast into space where they may eventually condense with other materials to generate even more stars. Indeed, scientists think that the encounter of a shock wave produced by a supernova and a GMC is responsible for vast numbers of new stars.

Cosmic recycling

With the life and death of each star, elements are created, transformed, and recycled.

The hydrogen in the air we breathe has probably been around since the Big Bang. The iron in our blood may have had its origins in the core of a star. Even the gold in our jewelry may have a history that includes a supernova shock wave. Maybe you feel insignificant when looking up on a starry night. You may think how infinitesimally small one human seems when compared to the vastness of the universe. But there is something grand in what you share with all humans, living things, continents, oceans, planets, moons, and suns. We are all of the same stuff—the stardust of a younger universe.

David Thielk is a science writer who lives in Port Townsend, WA. His article “On Board With Epoxy” appeared in the April 2000 issue of *ChemMatters*.

REFERENCES

Comins, N. F. and Kaufman, W. J. *Discovering the Universe, 4th Ed.;* W. H. Freeman: New York, 1997.

Cox, P. A. The Elements: Their Origin, Abundance, and Distribution; Oxford Science Publications: Oxford, 1989.

Goldsmith, D. *The Astronomers,*

On a separate sheet of paper to be handed in, please summarize and respond to this article. Describe the "who, what, when, where, why, how" of the reading. What were your thoughts/reactions as your read the article?

Lesson 3: Subatomic Particles & Their Properties **Date:_____**

Do now: You learned that an atom was the smallest unit of matter. That is not exactly true. Let's find out why...

Answer the following questions.

- What does the word "atomic" refer to?
- What does the pre-fix "sub" mean?
- What does the word "particle" mean? (Think back to Unit 1)
- Put them together... what is a "subatomic" particle?

Each subatomic particle has very unique physical properties that will in turn; affect the chemical properties of the atoms they make up.

In order to better understand these properties, draw an atom with the location of each subatomic particle relative to one another. Label each subatomic particle or include a key. *(Note... relative just means in relation to or compared to each other. For example, the chemical was relatively shiny, compared to the dull container. Or Henrietta is a small city, relative to the one I grew up in.)*

Understanding Atomic Structure...

The word nucleus of the atom is just like the nucleus of the cell that you learned about in Living Environment. One of the properties of the nucleus is that it is very dense compared to the rest of the atom. This is a qualitative observation. To put this into quantitative terms, we say that each of these subatomic particles has an approximate relative mass of 1 amu. In other words, both of these subatomic particles equal one amu.

The majority of the atom's mass comes from the dense center of the atom (the nucleus). However, most of the atom is not dense, it is made of empty space. Have you ever heard of the idea that opposites attract? This principle comes from science. Positives and negatives attract one another and this attraction holds the atom together. Positively charged particles are given the symbol p^+. The negatively charged subatomic particles are given the symbol e^-. The third type of subatomic particle has no charge and so Chemists say it is neutral. (A neutral party in an argument is one who has no opinion.) We call these particles neutrons (sounds like neutral), and use an n^0. Each of the three types of subatomic particles has a different charge so that they can all co-exist in the small space that is the atom.

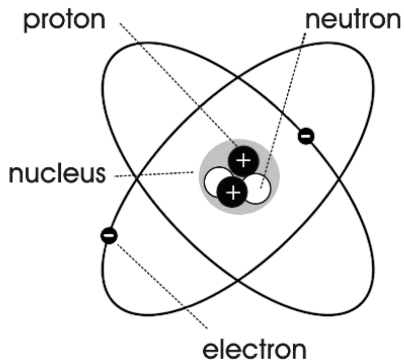
Notice that the +/-/0 for each symbol is in a specific location. This means something! The symbol is a way to abbreviate the subatomic particle, while still telling you something about it. This is just like your initials. If I wrote my initials as TFR, compared to TRF, compared to FTR, they would all mean something very different. This is the same for your date of birth or any other abbreviation or symbol. In Chemistry, the charge of the atom is always located in the upper right hand corner of the symbol.

Each type of atom has a specific number of protons. This is how we identify the atom. It is basically like its social security number... no two atoms can every have the same number of protons. We call these atomic numbers.

The word "atom" implies that the number of protons (positives) equal the number of electrons (negatives) to create a "neutral" atom.

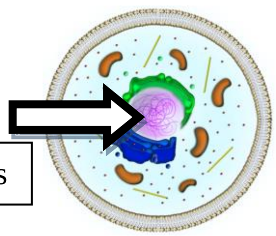
From now on, whenever you are asked for a charge, you should always include a positive or negative sign with it. If you do not, you are indicating that it is neutral, not positive or negative.

Check your understanding:
Examine the diagram. Answer the questions.



1. Based on the location of the subatomic particles, which subatomic particle is it easier to add or remove?

2. Where the nucleus is located in an animal the cell?



nucleus

3. Where is it located in an atom?

4. What does this mean in terms of the amount of mass that it has?

5. So, based on your diagram above, what two subatomic particles contribute to the density (make up the mass of the atom?) _______________ and ________________

6. What does the unit **"amu"** mean? ____

7. Why do you think we need to use amu's to measure the mass of an atom?

8. If I were to tell you that the mass of an atom was 22 amu's and had 13 positively charged particles, you would tell me that it has _____ protons and ______ neutrons.

9. What are **"mass numbers"?** ____________________________________

10. The positively charged subatomic particles are the___________________ and are in the nucleus.

11. The negatively charged subatomic particles are the __________ and are located in orbitals outside the nucleus.

12. What are **"atomic numbers"?** ____

13. So... if I were to tell you that an atom has 10 positively charged subatomic particles... you would tell me that it has _______ protons and ______ electrons, or in other words that it was neutral.

14. Since the nucleus does not have any electrons in it, if I were to ask you what the charge on the nucleus of the atom in the previous question is, or in other words, the nuclear charge of the atom, you would tell me _____ ______.

(+/-) (#)

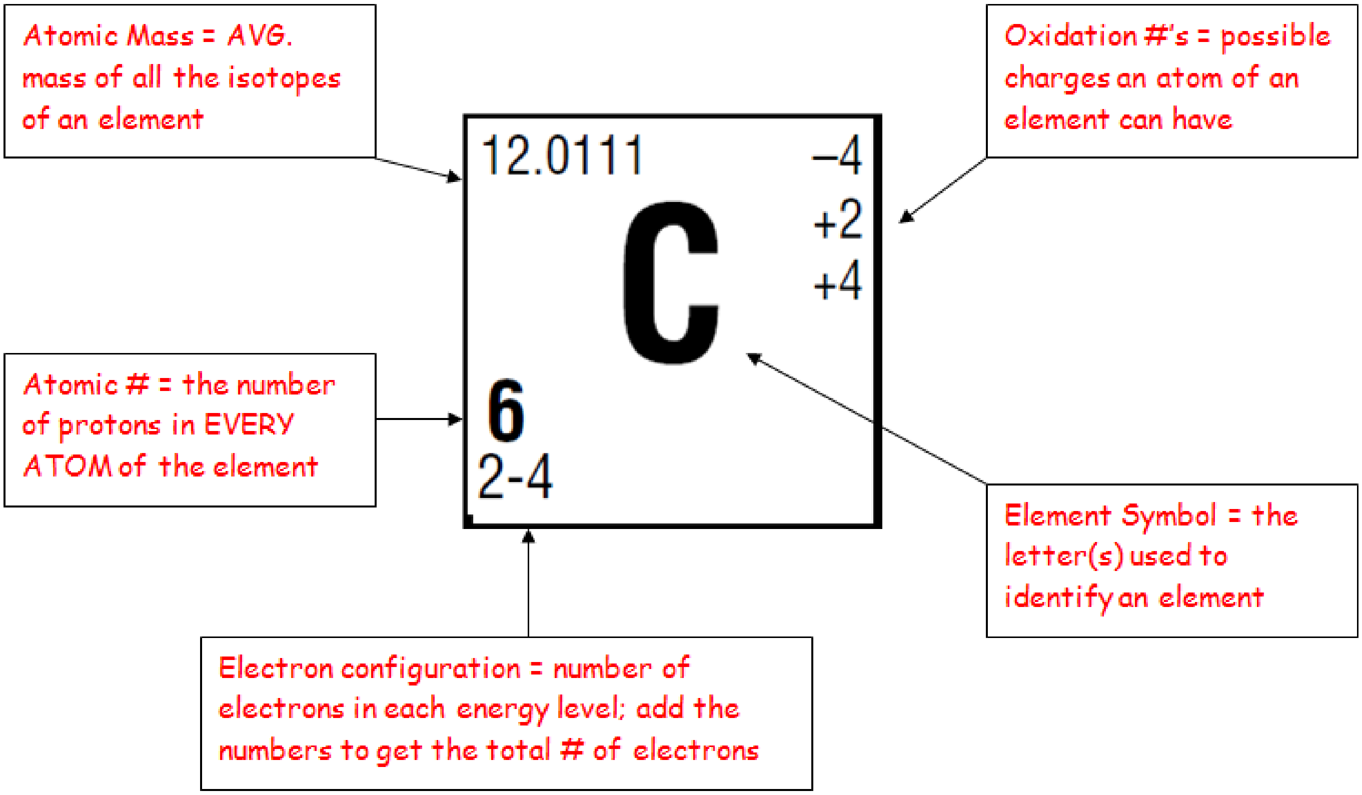
15. Atoms are electrically _______________.
(*positive*, *negative*, or *neutral*?)

16. This means that the number of ________
(p^+, n^0, or e^-?)
must equal the number of __________________.
(p^+, n^0, or e^-?)

Lesson 4: Vocabulary of the Periodic Table **Date:_______**

Do Now: Fill in the following table.

Particle	Charge	Mass	Location
neutron			
	+1	1	
electron			



Subatomic Particle	Charge	Relative Mass	Location	Symbol	How to Calculate
Proton	+1	1 amu	Nucleus	p^+	**Look at the atomic #**
Neutron	0	1 amu	Nucleus	n^0	**Mass # - Atomic #**
Electron	-1	1/1836th amu (negligible)	Outside nucleus	e- or e	**P = e- in neutral atom**

Mass number = sum of the protons and neutrons in an atom of an element

(p + n) = mass #

Nuclear Charge = charge w/in the nucleus; = to the # of protons or the atomic #

p = nuclear charge

Nucleons = any subatomic particles found w/in the nucleus; protons and neutrons

Check your understanding:

Using the definitions provided above please fill in the following chart.

Symbol	# Protons	# Neutrons	# Electrons	Atomic Number	Mass Number	Nuclear Symbol
Cl-35			17	17		$^{35}_{17}Cl$
	15	16				
C-14		8			14	$^{14}_{6}C$

Bag of Atoms Activity

Directions: During this activity, you be given a set of "oversized" atoms big enough to open and look inside. For each, you must count up the different subatomic particles ad fill in the information in the appropriate boxes. You must use your reference table and the key below to identify the element and fill in the chart.

Key:

Black=protons Clear=neutrons Electrons are ON the bag

Atom(Bag #)________

Number of Protons	
Atomic number	
Nuclear charge	
Number of electrons	
Mass number	
Number of Neutrons	
Element symbol	
Element name	

Atom(Bag #)________

Number of Protons	
Atomic number	
Nuclear charge	
Number of electrons	
Mass number	
Number of Neutrons	
Element symbol	
Element name	

Atom(Bag #)_______

Number of Protons	
Atomic number	
Nuclear charge	
Number of electrons	
Mass number	
Number of Neutrons	
Element symbol	
Element name	

Atom(Bag #)_______

Number of Protons	
Atomic number	
Nuclear charge	
Number of electrons	
Mass number	
Number of Neutrons	
Element symbol	
Element name	

Atom(Bag #)_______

Number of Protons	
Atomic number	
Nuclear charge	
Number of electrons	
Mass number	
Number of Neutrons	
Element symbol	
Element name	

Atom(Bag #)_______

Number of Protons	
Atomic number	
Nuclear charge	
Number of electrons	
Mass number	
Number of Neutrons	
Element symbol	
Element name	

Lesson 5: **Subatomic Particles & Ions** ***Date:_______***

Do Now: Answer the following questions.

Previously we learned that the number of protons and the number of electrons in an atom are equal leaving the atom with no overall positive or negative charge.

What do you think the charge of an atom that gained one electron would be?

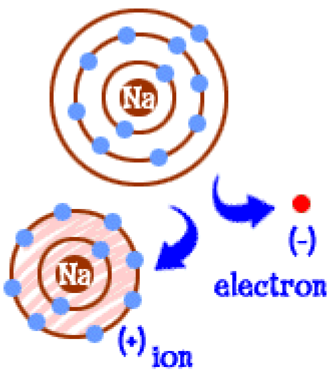
What would the charge of an atom that lost an electron be?

What is the charge of an atom?

A normal atom has a **neutral** charge with equal numbers of positive and negative particles. That means an atom with a neutral charge is one where the number of electrons is equal to the atomic number. Ions are atoms with extra electrons or missing electrons. When you are **missing an electron** or two, you have a **positive charge**. When you have an **extra electron** or two, you have a **negative charge**.

An Ion is an atom or molecule which has gained or lost one or more of its **valence electrons**, giving it a net positive or negative electrical charge.

Cations are POSITIVELY charged ions, whereas **Anions** are NEGATIVELY charged.



Check your understanding:

1.) In terms of subatomic particles, what is the difference between an atom and an ion?

2.) How can you determine the electrical charge on an ion?

3.) When an atom becomes an ion, does the element's nucleus change?

Insert ion pogil

Lesson 6: **Subatomic Particles & Isotopes** ***Date:_______***

Do Now:

1) What subatomic particle determines the identity of the element?
____

2) What subatomic particle determines the "chemistry" of the element?
____

3) What two subatomic particles make up the mass of the atom?
__________ & __________________

Read the following information.

Why Learn About This?

Atoms and isotopes are identified by the numbers of protons, neutrons, and electrons that they contain. Before you can understand the properties of atoms, how atoms combine to form molecules, and the properties of molecules, you must be familiar with the number of protons, neutrons, and electrons associated with atoms.

From the perspective of a chemist, the entire world is composed of atoms, and atoms are composed of protons, neutrons, and electrons. Protons and neutrons are about 2000 times heavier than an electron. A proton has a charge of +1, a neutron has no charge, and an electron has a charge of -1. The nucleus is very dense and very small compared to the entire atom.

The properties of atoms are determined by the numbers of protons, neutrons, and electrons that they contain. Atoms with the same number of protons but different number of neutrons are called **isotopes** of an element.

The isotopic notation for an atom includes the following information: symbol of the element, the element's atomic number (Z) which specifies the number of protons in the nucleus, and the mass number (A) which indicates the number of protons plus neutrons in the nucleus. [The number of electrons in a neutral atom is equal to the number of protons in the nucleus of the atom. The mass contributed by the electrons in an atom is very small, so it is not included when calculating the mass number.]

Atomic Symbol Notation

$${}^{A}_{Z}X$$

Mass Number
Atomic Symbol
Atomic Number

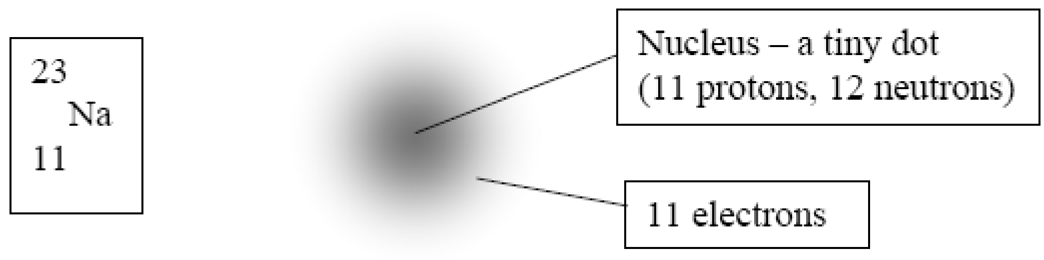
Subatomic Particles

Particle	Symbol	Relative Charge	Absolute Mass	Relative Mass
electron	e^-	-1	9.109×10^{-31} kg	0
proton	p^+	+1	1.673×10^{-27} kg	1
neutron	n^0	0	1.675×10^{-27} kg	1

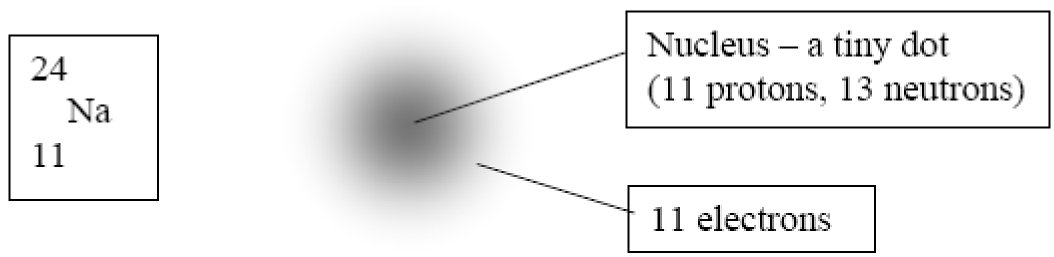
Model: Two Isotopes of Sodium

The diagrams below show representations of sodium isotopes. [Note: the diameter of an atom is about 10,000 times larger than the diameter of the nucleus, so the relative sizes of the atom and the nucleus are not accurately depicted in these diagrams.]

Isotope 1



Isotope 2



	Mass Number	**Atomic Mass**
Definition	The total number of protons and neutrons in an atom.	The weighted average of the naturally occuring isotopes of an element.
Explanation	Must be found for an individual atom. Can atoms ever have only half of a proton? No!!! This means that if the mass of a proton is 1 amu and the mass of a neutron is 1 amu, the mass number of an atom should never be a decimal! Decimals imply that the number was an average of multiple mass numbers.	Reported as a decimal on the periodic table.
Application	If a problem gives you the mass number and the number of protons (or tells you what element it is), you must find the number of neutrons by subtracting (mass number-protons)	If a problem gives you only the identity of an element, and does not give you the number of neutrons or the mass number, you can use the number given to you on the periodic table and round it to the nearest whole number.

Check your understanding:

1.) What information is provided by the atomic number, Z?

2.) What information is provided by the mass number, A?

3.) What is the relationship between the number of protons and the number of electrons in a neutral atom?

4.) Because of the relationship between the number of protons and number of electrons in an atom, what is the electrical charge of an atom?

5.) Where are the protons and neutrons located in an atom?

6.) What do the two sodium isotopes shown in the model have in common with each other?

7.) How do the two sodium isotopes shown in the model differ from each other?

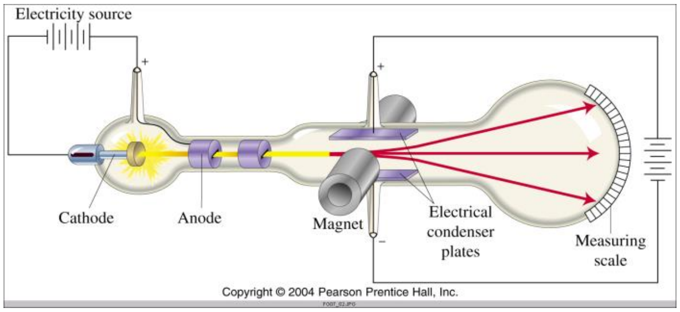
8.) What distinguishes an atom of one element from an atom of another element?

Lesson 7: Discovering Electrons: **Date:_________**

Do Now: Answer the following question using complete sentences.
Which subatomic particle can be lost or gained by an atom?

____

Thomson (1897): Experimented with Cathode Ray Tubes (CRTs)



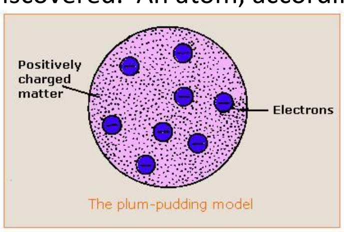
A CRT is similar to your TV. It has an **anode (A Negative electrode**) and a **cathode (A positive electrode)**. These are enclosed in an evacuated (air removed) glass container and when a charge is applied, the electrons flow from anode to cathode through the open space of the glass container.

View the following link : http://www.youtube.com/watch?v=XU8nMKkzbT8

As you watch the CRT, list your observations below. Are these qualitative or quantitative measurements?

Thomson observed these particles and determined that the particles:

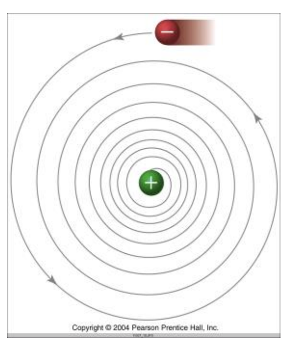
- Move at a very high speed (about 10% the speed of light)
- Have a negative charge
- Have a mass of about 1/2000 of a hydrogen atom (hydrogen is the smallest atom)
- Were the same regardless of which gas was used in the container or the metal used as the electrode
- Thomson's "plum pudding model" attempted to explain atomic structure once the electron (e- or e) had been discovered. An atom, according to this model, was a cluster of small positive and negative charges



.

Neils Bohr (Planetary) Model:

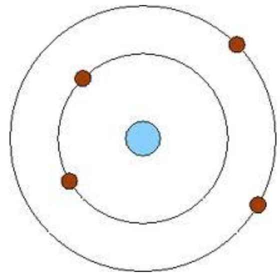
a. Rutherford proposed atoms had a positively charged nucleus, with negatively charged electrons orbiting around it. The only problem: He could not explain why the electrons would not just spiral into the nucleus (since opposite charges attract).



According to Rutherford's Theory

b. Bohr used data from atomic spectra to propose a soluton to the flaw in Rutherford's model. (*More on atomic spectra in Unit 7!*)

c. Electrons must exist in fixed, stable orbits (or energy levels), which are at a specific distance from the nucleus.



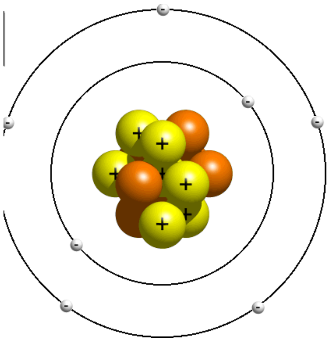
Check your understanding

1. In terms of subatomic particles, how did the work of both Thompson and Bohr change the way scientists viewed the structure of the atom?

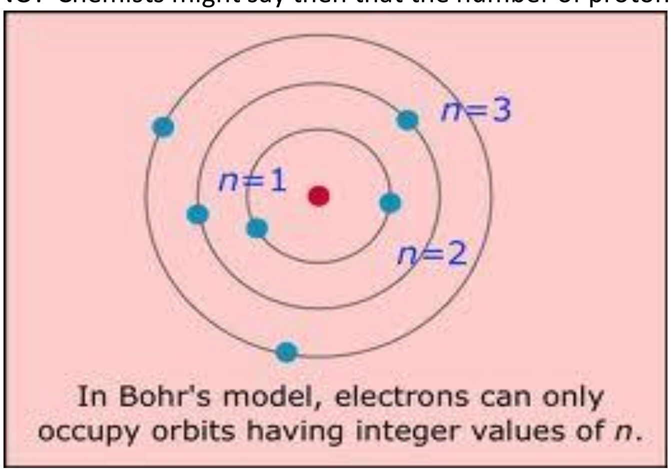
Lesson 8: Bohr Diagrams **Date:________**

Do Now: Answer the following question based on the picture below.

Why is the following model of an atom sometimes called the "planetary model?"



Look at the model of the atom proposed by Bohr (below). We know that the subatomic particle that determines the identity of the atom is the proton and it is located in the nucleus. *Place a p^+ in the proper location on the diagram above.* Does the identity of an atom ever change in chemical reactions? NO! So do you think that the number of protons ever changes in a chemical reaction? NO! Chemists might say then that the number of protons is stable or not changing.



1. **Why does this make sense based on the location of the protons in the diagram?**

Bohr did not yet know about neutrons. These would not come until much later. Neutrons are also located in the nucleus of the atom. *Place an n^0 on the diagram above to represent this subatomic particle*. Atoms of the same element may have different numbers of neutrons. These are known as isotopes. However, once an atom has a specific number of neutrons, this number will not change. For example, Cl-37 cannot give one of his neutrons to Cl-35!

2. **Why does this make sense based on the location of the neutrons in the diagram?**

Thomson had already discovered the electron. Bohr's major contribution was the proposal that electrons were not spread throughout the atom as Thomson thought, but that they must exist in fixed, stable orbits around the nucleus. *Label the electrons on the diagram below with an e^-.*

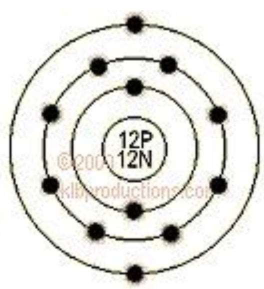
Because of Bohr's model of the atom, we describe the structure of an atom in terms of ENERGY LEVELS (aka "shells" or "orbits"). Since this subatomic particle is located on the outside of the atom, it is the subatomic particle that will have the most impact on the properties of the atoms, because it is most likely to be impacted by other atoms around it. We can use the structure of the electrons to help us predict these properties!

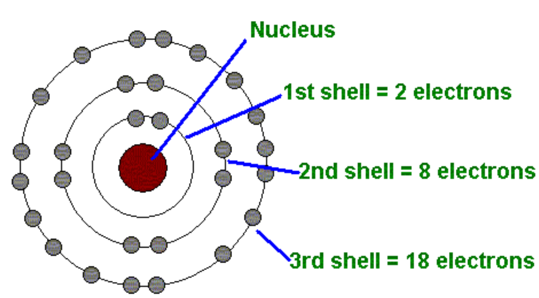
Bohr Diagrams are drawings that show the structure of the atom.

Step 1: Draw a nucleus and label it with the correct number of protons and neutrons.
Step 2: Look up the electron configuration for the element. (Use key on Periodic table.) The e- configuration tells us how many electrons are on each orbital.
Step 3: Draw the correct number of orbitals around the nucleus and label them with the correct number of electrons.

Ex: $^{24}_{12}Mg$

Ex: $^{37}_{17}Cl$





<u>Check your understanding:</u>

1. What subatomic particle is most important in determining the properties of atoms? Why?

2. Draw a bohr model for Sodium (Na).

Lesson 9: The Modern Model **Date:________**

Do Now: Read the following and answer the questions using complete sentences.

Review:

- Rutherford proposed an atomic model in which electrons move around a small positive nucleus.

- Rutherford's model could not explain the chemical properties of elements.

- In 1913, Bohr corrected Rutherford's Model –

    a. Electrons travel in concentric circular paths, or orbits, around the nucleus (sort of like the solar system).

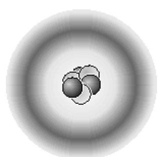
    b. Each possible electron orbit has a fixed energy.

    c. The energies an electron can have are called energy levels. (Electrons cannot have energy levels in between these levels.)

All of the previous models were building up to:

Modern Model: (Think of a FAN!)

a. aka - **Quantum Mechanical Model**, Wave Model, Wave Mechanical Model, Cloud Model, Electron Cloud Model



b. There is a probability for finding the electron in regions of space chemists today call "**orbitals.**"

Today

This model is the only one that scientists consider accurate. However, we would never have this model if all the others were not there for us to improve upon!

1) What is the main difference between Bohr's model and the Quantum Mechanical Model?

2) Compare and contrast the difference between Thomson's model and the Quantum Mechanical Model...

Practice: Comparing / Contrasting Atomic Models

1. What discoveries concerning the Modern Atomic Theory are each of the following scientists credited with?

   a. *Ernest Rutherford –*

   b. *John Dalton –*

   c. *J.J. Thomson –*

   d. *Neils Bohr –*

2. Draw each atomic model and identify which scientist is associated with it:

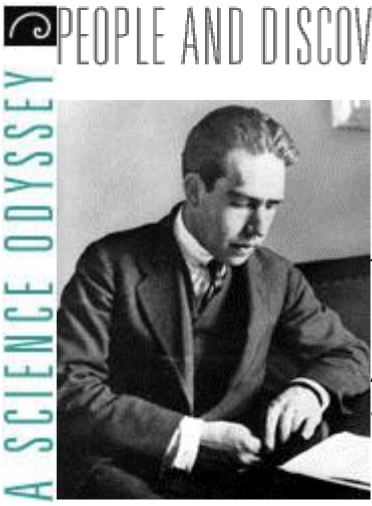
Rutherford	Bohr	Dalton	Thomson
Model Nickname:	*Model Nickname:* *"Planetary"*	*Model Nickname:*	*Model Nickname:*
Order:	*Order:*	*Order:*	*Order:*

Put these models in the order in which they occurred by numbering them 1-4 above.

Lesson 10 : Article Analysis *Date:*_______

Do Now: Read the following article.

***Niels Bohr and Ernst Rutherford:The Life of a Scientist*.**



Niels Bohr
1885 - 1962

Niels Bohr was born and educated in Copenhagen, Denmark. He lived, worked, and died there, too. But his mark on science and history was worldwide. His professional work and personal convictions were part of the larger stories of the century.

At the University of Copenhagen, he studied physics and played soccer (though not as well as his brother, who helped the 1908 Danish soccer team win an Olympic silver medal). After receiving his doctorate in 1911, Bohr traveled to England on a study grant and worked under J.J. Thomson, who had discovered the electron 15 years earlier.

Bohr began to work on the problem of the atom's structure. Ernest Rutherford had recently suggested the atom had a miniature, dense nucleus surrounded by a cloud of nearly weightless electrons. There were a few problems with the model, however. For example, according to classical physics, the electrons orbiting the nucleus should lose energy until they spiral down into the center, collapsing the atom. Bohr proposed adding to the model the new idea of quanta put forth by Max Planck in 1901. That way, electrons existed at set levels of energy, that is, at fixed distances from the nucleus. If the atom absorbed energy, the electron jumped to a level further from the nucleus; if it radiated energy, it fell to a level closer to the nucleus. His model was a huge leap forward in making theory fit the experimental evidence that other physicists had found over the years. A few inaccuracies remained to be ironed out by others over the next few years, but his essential idea was proved correct. He received the Nobel Prize for this work in 1922, and it's what he's most famous for. But he was only 37 at the time, and he didn't stop there. Among other things, he put forth the theory of the nucleus as a liquid drop, and the idea of "complementarity" -- that things may have a dual nature (as the electron is both particle and wave) but we can only experience one aspect at a time.

In 1912 Bohr married Margrethe Nørlund. They had six sons, one of whom, Aage, followed his father into physics -- and into the ranks of Nobel Prize-winners. Bohr returned to Denmark as a professor at the University of Copenhagen, and in 1920 founded the Institute for Theoretical Physics -- sponsored by the Carlsberg brewery! Bohr remained director of the institute for the rest of his life, except for his absence during World War II. Bohr's personal warmth, good humor ("Never express yourself more clearly than you can think," he once said), and hospitality combined with world events to make Copenhagen a refuge for many of the century's greatest physicists.

After Hitler took power in Germany, Bohr was deeply concerned for his colleagues there, and offered a place for many escaping Jewish scientists to live and work. He later donated his gold Nobel medal to the Finnish war effort. In 1939 Bohr visited the United States with the news from Lise Meitner (who had escaped German-occupied Austria) that German scientists were working on splitting the atom. This spurred the United States to launch the Manhattan Project to develop the atomic bomb. Shortly after Bohr's return home, the

German army occupied Denmark. Three years later Bohr's family fled to Sweden in a fishing boat. Then Bohr and his son Aage left Sweden traveling in the empty bomb rack of a British military plane. They ultimately went to the United States, where both joined the government's team of physicists working on atomic bomb at Los Alamos. Bohr had qualms about the consequences of the bomb. He angered Winston Churchill by wanting to share information with the Soviet Union and supporting postwar arms control. Bohr went on to organize the Atoms for Peace Conference in Geneva in 1955.

In addition to his major contributions to theoretical physics, Bohr was an excellent administrator. The institute he headed is now named for him, and he helped found CERN, Europe's great particle accelerator and research station. He died at home in 1962, following a stroke.

"An expert is a man who has made all the mistakes which can be made, in a very narrow field."

A SCIENCE ODYSSEY

PEOPLE AND DISCOVERIES

Ernest Rutherford
1871 - 1937

Ernest Rutherford's family emigrated from England to New Zealand before he was born. They ran a successful farm near Nelson, where Ernest was born. One of 12 children, he liked the hard work and open air of farming, but was a good student and won a university scholarship. After college, he won another scholarship to study at Cambridge University in England -- a turning point in his life. There he met J.J. Thomson (who would soon discover the electron), and Thomson encouraged him to study recently-discovered x-rays.

This was the start of a long, productive, and influential career in atomic physics. Rutherford eventually coined the terms for some of the most basic principles in the field: alpha, beta, and gamma rays, the proton, the neutron, half-life, and daughter atoms. Several of the century's giants in physics studied under him, including Niels Bohr, James Chadwick, and Robert Oppenheimer.

Early on he found that all known radioactive elements emit two kinds of radiation: positively and negatively charged, or alpha and beta. He showed that every radioactive element decreases in radioactivity over a unique and regular time, or half-life, ultimately becoming stable. In 1901 and 1902 he worked with Frederick Soddy to prove that atoms of one radioactive element would spontaneously turn into another, by expelling a piece of the atom at high velocity. Many scientists of the day scorned the idea as alchemy. They stuck with the age-old belief that the atom is indivisible and unchangeable. But by 1904 Rutherford's publications and achievements gained recognition. He was an extremely energetic researcher: in the span of seven years, he published 80 papers.

In 1907 he went to the University of Manchester and with Hans Geiger (of the Geiger counter) set up a center to study radiation. In 1909 he began experiments that were to change the face of physics. He discovered the atomic nucleus and developed a model of the atom that was similar to the solar system. Like planets, electrons orbited a central, sun-like nucleus. Acceptance of this model grew after it was modified with quantum theory by Niels Bohr. For his work with radiation and the atomic nucleus, Rutherford received the 1908 Nobel Prize in chemistry. He was slightly put out, since he was a physicist and felt a bit superior to chemistry! In 1914 Rutherford was knighted.

During World War I, he left his research to help the British Admiralty with problems of submarine detection, but was soon back in the lab. He managed to produce the disintegration of a non-radioactive atom, dislodging a single particle. The particle had a positive charge, so it must have come from nucleus: he called this new particle a proton. With this experiment, he was the first human to create a "nuclear reaction," though a weak one. In 1919 he took over as director of the Cavendish Laboratory. His warm, outgoing personality made him an outstanding mentor to researchers attracted there by his scientific achievements.

He took on more supervision and less direct research as years went by. In 1931 he was made the first Baron Rutherford of Nelson, allowing him to join the House of Lords. He was fiercely anti-Nazi, and in 1933 he served as president of the Academic Assistance Council, established to help German refugees. He would not personally help chemist Fritz Haber, however, who had been instrumental in creating chemical weapons in World War I. Rutherford died two years before the discovery of atomic fission.

"All science is either physics or stamp collecting."

Directions: Scientists are people too and can lead very interesting lives. Just as our childhood and environment mold us into who we are, the life experiences of a scientist mold their character and ability to achieve greatness. Read the attached two passages about two scientists that were instrumental in defining the structure of the atom. Answer the following questions on a separate piece of paper to be collected upon completion of your reading.

1. What type of education did both scientists receive in their youth and how did it influence their careers? Do they have anything in common?

2. The work of one scientist can very much influence the work of another scientist. How does this statement apply to Bohr and Rutherford? Support your answer with examples from the passage.

3. Both scientists lived and worked during Hitler's reign. How did this influence their ability to complete their work? Support your answer with examples from the passage.

4. If Rutherford were still alive, what do you think his reaction would be to the creation of the atomic bomb and Bohr's role in its creation?

<u>Lesson 11: Electrons and Energy</u> **Date:______**

<u>Do Now:</u> *Answer the following question using complete sentences.*

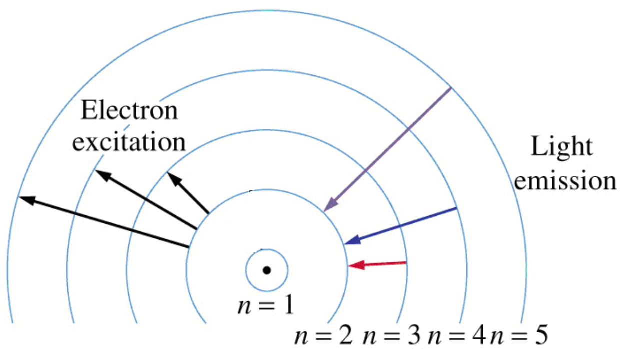
What colors make up"white light?"

The modern or "quantum mechanical" model of the atom describes energy levels as being further subdivided into sublevels and **orbitals**. The word "orbital" is one you need to know, and simply refers to a region of space around the nucleus where there is a high probability of finding an electron. The more electrons an atom has, the more orbitals it will use. Each orbital contains a maximum of 2 electrons.

Each electron in an atom has a particular amount of energy depending on how close they are to the nucleus. Electrons in orbitals that are **closer to the nucleus** are more energetically **stable and are at a lower energy**. When all the electrons in an atom are in their lowest possible energy levels, the atom is said to be in the "**ground state**." The ground state electron configuration is the one displayed on the periodic table below each element.

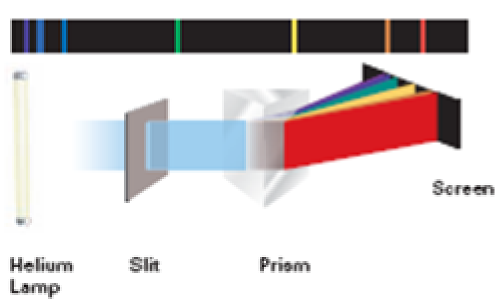
When an atom interacts with an outside energy source such as heat, light or electricity, the electrons can be affected. The most accessible and therefore most likely to be affected electrons are the valence electrons. If the electron can **absorb** just the right amount of **energy** to pop it to a **higher energy level**, it will indeed do this. The atom is now described as being in the "**excited state**." An atom in the excited state is unstable and will immediately **emit the energy** *in the form of light* as the electron(s) **return to the ground state**. The excited state configuration of an atom has the **same number of electrons** as the ground state. For example, oxygen in the ground state is 2-6, but in the excited state might be 2-5-1, or 1-7, or 1-6-1. In all cases the total number of electrons is that of an atom of oxygen… that is 8 electrons.

On the left of the diagram, electrons are shown being excited from the 2nd energy level (n = 2) to the 3rd, 4th and 5th energy levels. As they return to their original energy level (to the ground state), they emit their extra energy in the form of a particular frequency (color) of light.



The specific set of frequencies of light emitted by atoms as they return to the ground state produces a **bright-line spectrum**. Every element has its own unique spectrum, and could be thought of as the "fingerprint" of that element. A spectrum of samples of unknown composition can be observed in order to identify the elements present. Much of what we know about the structure and history of the universe has been figured out by observing the spectra of stars.

This diagram shows an example of how a spectrum is taken and what it would look like. It may be helpful to look at the COLOR PICTURE on p 141 of your Prentice Hall textbook.



<u>Another Resource:</u>

- ☐ http://www.visionlearning.com/library/module_viewer.php?mid=51&l=&c3=
  (scroll down to "Bohr Atom: Quantum Behavior of Hydrogen" animation)

Check your Understanding:

1. What is an "Orbital?"

____

____

2. What is the most electrons that can occupy one orbital? ________

3. What is the relationship between the distance an electron is from the nucleus, and its energy?

____

____

4. What is the "ground state" electron configuration for an atom of phosphorus?

____

5. How does an atom enter the "excited state?"

____

____

6. What does an atom in the excited state do as its electron(s) return to the ground state?

____

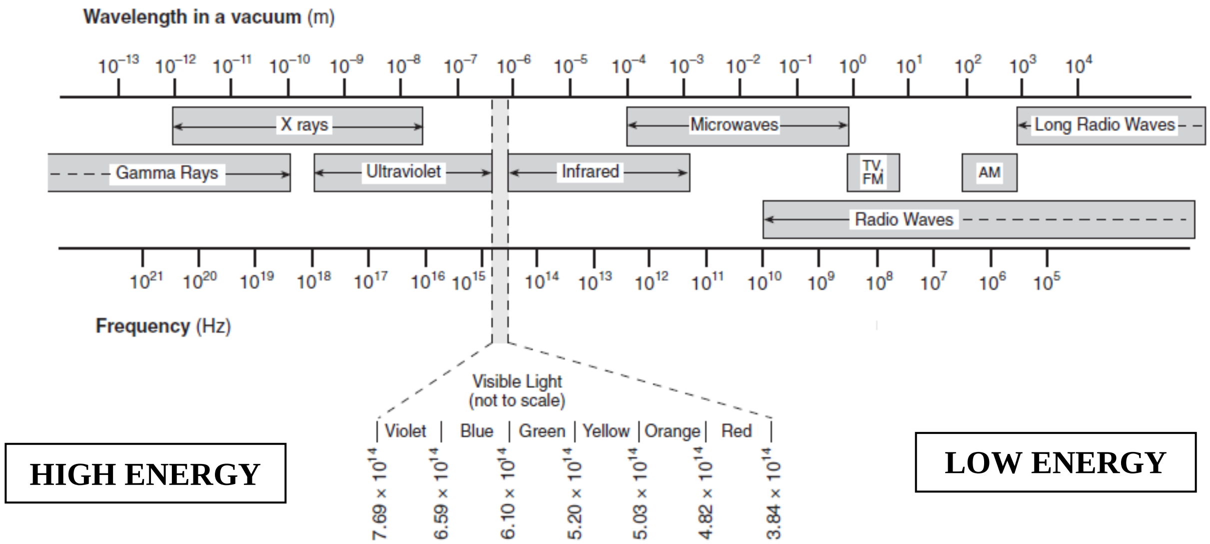
____

7. (T/F) ____ When an atom becomes excited it loses electrons.

Lesson 12: Excited vs. Ground State **Date:_______**

We need to consider the nature of light, or what is called the **electromagnetic spectrum**.

The Electromagnetic Spectrum



Do now:

Answer the questions below based on the electromagnetic spectrum above.

1.) The energy of light ______________________________ from red to green to blue.
(increases, decreases, or *remains the same?)*

2.) The shorter the wavelength of light, the ___________________ its energy.
(higher or *lower?)*

3.) The shorter the frequency of light, the ______________ its energy.
(higher or *lower?)*

4.) Energy and wavelength have a(n) _________________________ relationship.
(direct or *inverse?)*

5.) Energy and frequency have a(n) __________________________ relationship.
(direct or *inverse?)*

6.) In terms of energy, order the following forms of light from the highest (#1) to the lowest (#7):
red, blue, green, yellow, orange, infrared, ultraviolet

Let's look at a lithium atom…

1

Li
2-1
"Ground State"

Go to excited state = Add Energy

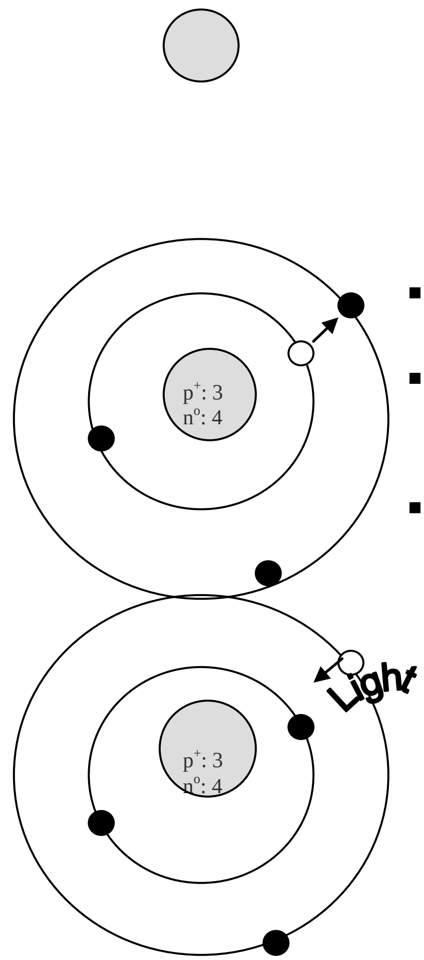
2

Li
1-2
"Excited State"

Return to ground state = Release Energy

3

Li
2-1
"Ground State"

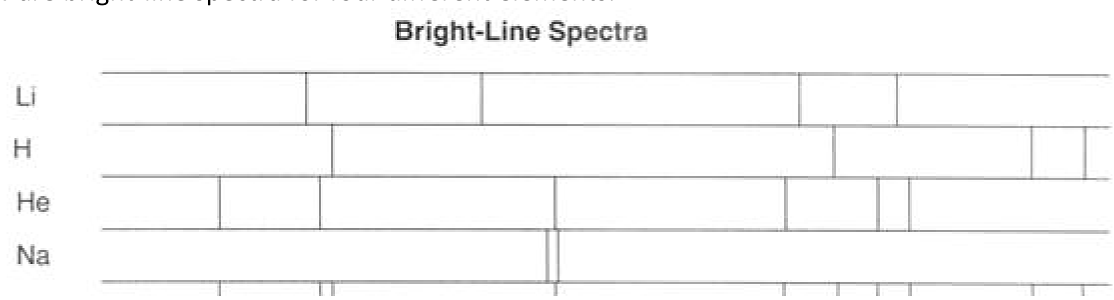


- electron **absorbs** energy
- electrons jumps to a higher energy level.
- atom is now in the "excited state"

- When electron returns to a lower energy level, energy is **emitted** in the form of **LIGHT**
  - at specific wavelengths
  - bright line spectra produced
- atom is now back in the "ground state"

Bright-Line Spectra

When an electron returns to ground state from the excited state, light is emitted at specific frequencies. If you were to observe the light emitted through a diffraction grating certain colors would appear brighter depending on which element you were observing. Spectral lines are like an element's fingerprint. They are unique and can be used to identify the element. Below are bright-line spectra for four different elements.



Check your understanding:

1. When electrons in an atom in the excited state fall back to lower energy levels, energy is

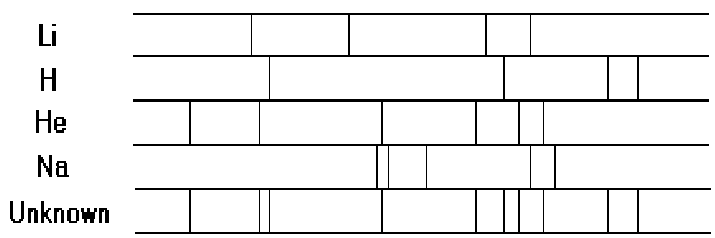
    1. absorbed, only
    2. released, only
    3. neither released nor absorbed
    4. both released and absorbed

2. What is the total number of valence electrons in a fluorine atom in the ground state?

    1. 5
    2. 2
    3. 7
    4. 9

3. When the electrons of an excited atom return to a lower energy state, the energy emitted can result in the production of

    1. lightening
    2. isotopes
    3. protons
    4. spectra



4.

The diagram shows the characteristic spectral line patterns of four elements. Also shown are spectral lines produced by an unknown substance. Which pair of elements is present in the unknown?

1. lithium and sodium
2. sodium and hydrogen
3. lithium and helium
4. helium and hydrogen

Real World Application:

Directions: Read the following passage related to the bright line spectra and the study of stars. Then answer the following questions based on the passage and your knowledge of chemistry.

Spectra and What Scientists Can Learn From Them

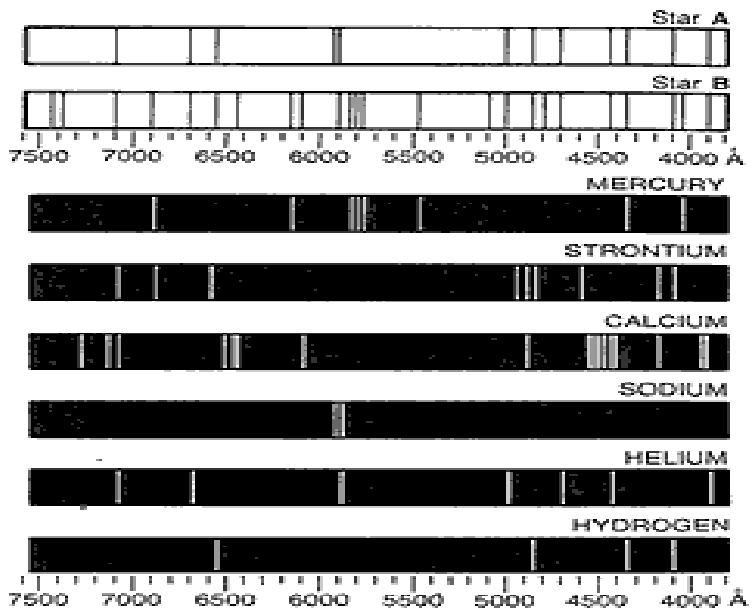
Each element in the periodic table can appear in gaseous form and will produce a series of bright lines unique to that element. Hydrogen will not look like helium which will not look like carbon which will not look like iron... and so on. Thus, astronomers can identify what kinds of stuff are in stars from the lines they find in the star's spectrum. This type of study is called spectroscopy. The science of spectroscopy is quite sophisticated. From spectral lines astronomers can determine not only the element, but the temperature and density of that element in the star. The spectral line also can tell us about any magnetic field of the star. The width of the line can tell us how fast the material is moving. We can learn about winds in stars from this. If the lines shift back and forth we can learn that the star may be orbiting another star. We can estimate the mass and size of the star from this. If the lines grow and fade in strength we can learn about the physical changes in the star. Spectral information can also tell us about material around stars. Spectroscopy is one of the fundamental tools which scientists use to study the Universe.

Excerpt from NASA.gov

Questions:

1. How might emission spectra be used when studying stars?

2. Determine what gas(es) are present in the spectra of star A. Give evidence to support



your answer.

____
____
____
____
____
____

Lab Activity : Isotopes Date: ________

mass number

X

atomic number

Background: an atom is missing a neutron or has an extra neutron. That type of atom is called an **isotope**. An atom is still the same element if it is missing an electron. The same goes for isotopes. They are still the same element. They are just a little different from every other atom of the same element. For example, there are a lot of carbon (C) atoms in the Universe. The normal ones are carbon-12. Those atoms have 6 neutrons. There are a few straggler atoms that don't have 6. Those odd ones may have 7 or even 8 neutrons. As you learn more about chemistry, you will probably hear about carbon-14. **Carbon-14** actually has 8 neutrons (2 extra). C-14 is considered an isotope of the element carbon.
If you have looked at a periodic table, you may have noticed that the **atomic mass** of an element is rarely an even number. That happens because of the isotopes. If you are an atom with an extra electron, it's no big deal. Electrons don't have much of a mass when compared to a neutron or proton.

Atomic masses are calculated by figuring out the amounts of each type of atom and isotope there are in the Universe. For carbon, there are a lot of C-12, a couple of C-13, and a few C-14 atoms. When you average out all of the masses, you get a number that is a little bit higher than 12 (the weight of a C-12 atom). The **average atomic mass** for the element is actually 12.011. Since you never really know which carbon atom you are using in calculations, you should use the average mass of an atom.

Objective: To determine the identities of unknown atoms based on subatomic particles.

Procedure:

1. The black pom-poms represent protons and the red represent neutrons.
2. Count the amount of black and pom-poms and record.
3. Rotate to each station and repeat.
4. Use the reference tables to identify the atoms.

Data:

Globe Number	Black pom-poms	Red pom-poms	Isotope symbol
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			

Analysis:

1. Which subatomic particle is used to identify an element?

2. Where there any atoms in which the number of black outnumbered the number of red pom-poms? Why?

3. List atoms that have the same number of protons. What do they have in common?

4. How are the atoms you have listed in question four different?

5. Define the term isotope.

Lab activity: Flame Test **Date:_______**

Background: When all the electrons are in their lowest energy level the atom is in its **ground state**. When these atoms are given energy, the electrons absorb the energy, which allows them to "jump up" to a higher energy level. This is called the **excited state**. However, the excited state is unstable so the electrons will lose the energy and "fall down" to ground state. When the energy is lost, some of it comes off in the form of light. Only metals with loosely held electrons could be excited in a Bunsen burner flame and give off colored light.

Objective: To observe the colors produced by metallic ions when they are vaporized in a flame and use them to identify an unknown sample.

Safety: Goggles, aprons ** You must be wearing goggles at all time and tie back loose hair and clothing.

Materials: Nichrome loop saturated in solutions of Na^+, K^+, Li^+, Ca^{2+}, Sr^{2+}, Ba^{2+} and Cu^{2+}.

Procedure:

1. Create a table including the metallic ion and its flame color.
2. Set up and light a Bunsen burner.
3. Use the nichrome loop to obtain a sample from the beaker with the metallic sample.
4. Burn the liquid in the loop in the hottest part of the flame (the blue part).
5. Observe and record the color produced.
6. Clean the loop by placing it in the beaker of HCl(hydrochloric acid) and heating the loo[.
7. At the command of your teacher, move to the next table (clockwise), and repeat.

Data:

Ion	Flame Color
Na^+	
K^+	
Li^+	
Ca^{+2}	
Sr^{+2}	
Ba^{+2}	
Cu^{+2}	
Unknown	

Analysis:

1. Explain why the flame test is not a very accurate way to identify elements.

2. Which ions produced similar colors in the flame tests?

3. If we use spectroscopic glasses while observing the flames, what would we see?

4. In terms of electrons, state one similarity between the flame test and spectra labs.

5. Based on your data, which element was the unknown composed of?

Lab activity: Spectrum of Light Lab **Date:________**

Background: The tubes used in this experiment are filled with gases that we are interested in studying. An electric current will run through the gas, providing the electrons in the gas atoms to move to a higher energy level. When the electrons fall back down to their lowest energy levels they release energy in the form of radiant energy. The radiant energy can be seen using spectroscopic glasses, which diffract the light. The spectrum appears as a series of colored vertical lines that are unique to each element.

Objective: To understand the process by which the gases give off colored light and be able to identify an unknown gas by its spectra.

Procedure:

1. Obtain and wear a pair of spectroscopic glasses.
2. As each gas is demonstrated, write the name of the gas, its visible color (without your glasses) and the spectrum colors (with your glasses). During the lab use crayons or colored pencils to record the color of the light you see. If you see multiple lines of the same color, show approximately how many.

Data:

Gas	Visible color	Spectra colors	Color

Analysis:

1. Define valence, excited state, and ground state.

2. Draw the Bohr diagrams for Hydrogen and Neon.

3. Based on the Bohr diagrams, which element do you think will have more lines in its spectra? Why?

4. Explain in your own words how is the bright line (emission) spectra produced.