<u>The atomic model</u>

In this exercise, we will be examining the development of atomic theory. Atomic Theory has developed over 2000 years and has been improved by hundreds of scientists. We will be focusing the landmark theorists, chemists, or physicists. Some of the theories were disproved or expanded by other scientists; however, we study the development to explore how experiments proved pieces of the theory. It should be noted that the study of atomic theory and the atom continues to this day. **<u>Atomic Theory is one of the bases of chemistry. What atoms of composed of and how atoms' particles act will be a common theme throughout this class.</u>**

<u>Directions</u> – In this exercise you will read the following descriptions of various persons that contributed to atomic theory. In your groups you will demonstrate your knowledge of one of these persons by completing the chart I have provided to your assigned person.

Group 1 – Democritus

Group 2 – Dalton

Group 3 – Thomson

Group 4 - Rutherford

Group 5 - Bohr

<u>Democritus (460 B.C.E – 370 B.C.E)</u>

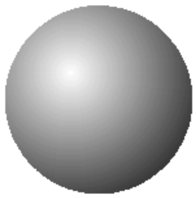
Democritus is a Greek Philosopher born 460 B.C. Democritus was born in Abdera, Greece in 460BC. He lived to be 90 years old, dying in the year 370BC. He studied natural philosophy in Thrace, Athens, and Abdera, Greece. He enjoyed studying geometry as well. Democritus traveled to many places some of which including India, Egypt, and Babylon. Democritus was never married.

His mentor, **<u>Leucippus</u>**, originally came up with the atomic theory, but it was then adopted by Democritus. The atomic theory stated that "The universe is composed of two elements: the atoms and the void in which they exist and move." According to Democritus atoms were miniscule quantities of matter. Democritus hypothesized that atoms cannot be destroyed, differ in size, shape and temperature, are always moving, and are invisible. He believed that there are an infinite number of atoms. This hypothesis was created in 465BC.

He formulated his own Democritus Atomic Model. His atomic theory states that everything is physically made op of atoms. He stated that atoms are indivisible and can never be broken down into pieces. He added that in between atoms are empty spaces, the more empty space the heavier the atom gets. This on the other hand was opposed and is only based on his opinions but not studied geometrically. Democritus Atomic Model talks about the atoms that can never be destroyed nor created.

Democritus believed that atoms are always moving and comes in different shapes and sizes. His theory states that all matter is made up of atoms and they are invisible. He stated that atoms are homogenous and that atoms are solid. Atoms cannot be destroyed nor created and changed. Atoms differ in size, shape, weight position and arrangement. They are space between atoms. Oil is made up of smooth solid atoms that can easily pass each other. Liquid has large round atoms and solids are made with pointy small solid atoms.

Democritus atomic model is made up with a sphere that cannot be seen or invisible. The sphere has no nucleus or electrons. They differ in shape, size and temperature. Democritus drew this model showing that atoms cannot be destroyed in any form or in any way.



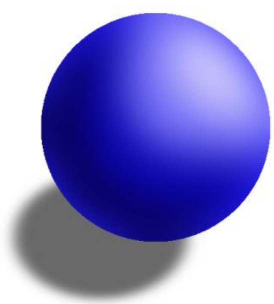
Democritus
(400 B.C.)

This is Democritus' atomic theory exactly:
1.All matter consists of invisible particles called atoms.
2. Atoms are indestructible.
3. Atoms are solid but invisible.
4. Atoms are homogenous.
5. Atoms differ in size, shape, mass, position, and arrangement.
->Solids are made of small, pointy atoms.
->Liquids are made of large, round atoms.
->Oils are made of very fine, small atoms that can easily slip past each other.

Dalton (1766 – 1844)

John Dalton was born in England in 1766. He was a teacher who spent his spare time doing scientific experiments on the weather prediction specifically the behavior of gasses in the air. Dalton gathered evidence for the existence of atoms by measuring the masses of elements that combine when compounds form. Dalton developed a theory to explain why the elements in a compound always join in the same way. Dalton proposed the theory that all matter is made up of individual particles called atoms which cannot be divided. In the model of atoms based on Dalton's theory, the elements are solid spheres. Each type of atom is represented by a tiny, solid sphere, where each sphere has a different mass.

Dalton's theories postulated that all elements are composed of atoms, of which the atoms of the same element have the same mass, and atoms of different elements have different masses. Compounds therefore contain atoms of more than one element. In a particular compound, atoms of different elements always combine in the same way. Dalton performed experimentation showing the masses of compounds containing known elements to show data that supported his theories. Over time, scientists found that not all of



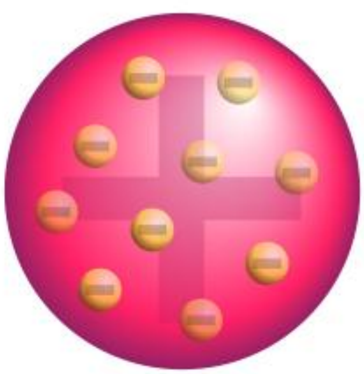
Dalton's ideas where correct and Dalton's model was revised.

Thomson (1856 – 1940)

JJ Thomson used an electric current to learn more about the structure of atoms. Thomas used a device called a cathode ray. At the center of device was a sealed glass tube from which most of the air could be removed. At each end of the tube there were metal disks with wires connecting the disks. The wires are attached to an electronic current. When the current is on, one disk becomes negatively charged and the other disk becomes positively charged. A ray appears in the space between the disks. Thomason hypothesized that the beam was a stream of charged particles that interacted with the air in the tube and caused the air to "glow". In one experiment Thomson placed a pair of charged metal plates on either side of the glass tube. The plates caused the beam to deflect, or bend, from its straight path. Thomson observed that the beam was repelled by the negatively charged plate and attracted by the positively charged plate.

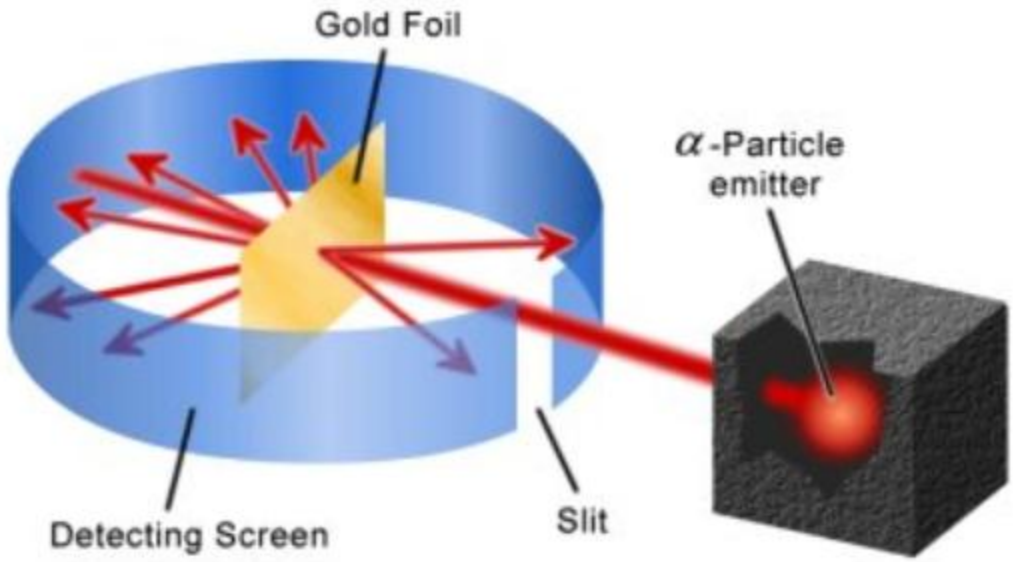
Thomson concluded that the particles in the beam had a negative charge because they were attracted to the positive plate. He hypothesized that the particles came from inside atoms. This was supported by two pieces of experimental evidence: 1.) No matter what metal Thomson used for the disk, the particles produced were identical. 2.) The particles had about $1/2000^{th}$ the mass of a hydrogen atom, the lightest atom. Thomson's discovery changed how scientists thought about atoms (remember previous models were thought to be solid balls. Thomson's experiments led to theories that atoms are made of even smaller particles. In the Thomson Model

1.) Atoms are neutral – meaning they have neither negative nor positive charges
2.) Negative charges are scattered around a positively charged mass of matter, this was named the "plum pudding model". Think of a scoop of chocolate chip model, where the chips are negative particles that are spread evenly through a mass of positively charged matter which is represented by the vanilla ice cream.



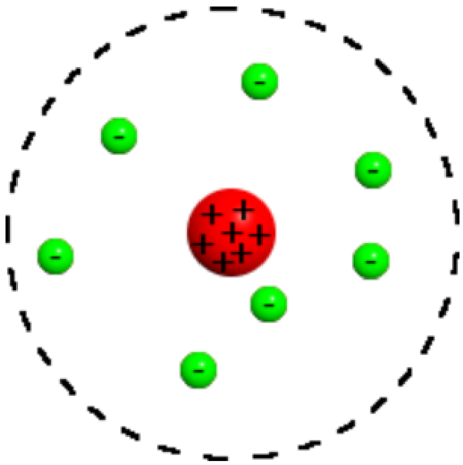
Rutherford (1871 – 1937)

Ernest Rutherford was the first to discover the alpha particle. The particle is a positively charged fast moving particle. In 1909 Rutherford had one of his students, Ernest Marsden, to perform an experiment to explore what happens when alpha particles are passed through gold sheets. Recall that according to Thompson's model, an atom was composed of a mass of positive charge even spread throughout the atom. Rutherford hypothesized that the mass and charge at any location in the gold would be too small to change the path of an alpha particle (a fast moving positive particle). He predicted that most particles would travel in a straight path from their source to a screen that lit up when they struck it. Those few that did not pass straight through would be deflected only slightly.



Marden used equipment set up like the picture above. He aimed a narrow beam of alpha particles at the gold. The screen around the gold was made of a material that produced a flash of light when struck by the fast-moving positive alpha particles. By observing the flash, Marden could figure out the path of an alpha particle after it passed through the gold. Based on Thompson's model, Rutherford expected that the many alpha particles would penetrate straight through the atoms striking the detecting screen. The experiment did not support this hypothesis. In fact more particles were deflected than expected. About one out of every 20,000 was deflected by more than 90 degrees. Some of the alpha particles behaved as though they had struck an object and bounced straight back.

The alpha particles whose paths were deflected must have come close to another charged object. The closer they came, the greater the deflection was. But many alpha passed through the gold without being deflected. From these results, Rutherford concluded that the positive charge of an atom is not evenly spread throughout the atom. It is concentrated in a very small, central area that Rutherford called the nucleus. The nucleus is a dense positively charged mass located in the center of the atom. (the plural of nucleus is nuclei). Rutherford proposed a new model, where all of the atoms positive charge are concentrated in the center of the atom. The alpha particle whose paths were deflected by more than 90 degrees came very close to a nucleus. The alpha particles whose paths were not bent moved through the space surrounding the nuclei without coming very close to the nucleus. The nucleus is relatively small – imagine the Houston Astrodome which is nine acres and seats more than 60,000 people. The roof of the stadium rises to a height of 202 feet above the center of the field. If an atom has the same volume as the stadium, the nucleus would have the volume of a marble. The total volume of an atom is about a trillion times the volume of a nucleus.

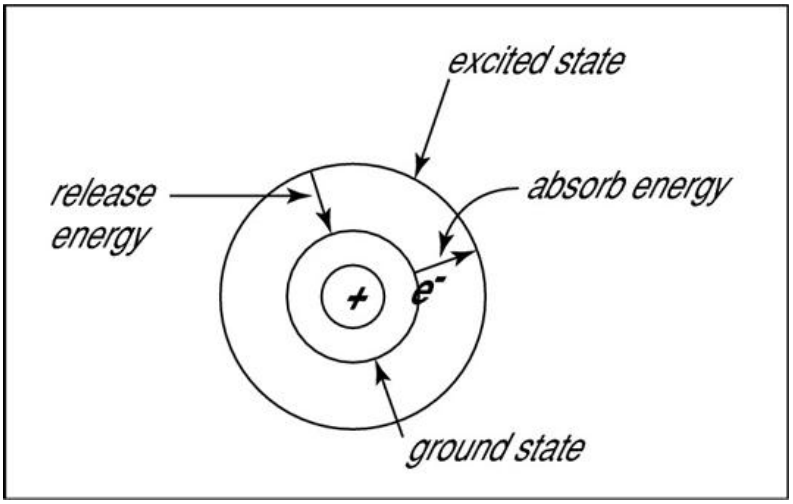


<u>Niels Bohr</u>

In 1913, Niels Bohr, depicted the atom as a small, positively charged nucleus surrounded by electrons that travel in circular orbits around the nucleus—similar in structure to the solar system, but with electrostatic forces providing attraction, rather than gravity. This was an improvement on earlier models. The Bohr model is a quantum-physics–based modification of the Rutherford model; many sources combine the two, referring to the **Rutherford–Bohr model**. The model's key success lay in explaining experimental data completed by another scientist. This other scientist, Rydberg, had produced a formula through his experimentation; it did not gain a theoretical underpinning until the Bohr model was introduced. Not only did the Bohr model explain the reason for the structure of the Rydberg formula, it also provided a justification for its empirical results in terms of fundamental physical constants.

- The Bohr model shows that the electrons in atoms are in orbits of differing energy around the nucleus (think of planets orbiting around the sun).
- Bohr used the term *energy levels* (or *shells*) to describe these orbits of differing energy. He said that the energy of an electron is *quantized*, meaning electrons can have one energy level or another but nothing in between.
- The energy level an electron normally occupies is called its *ground state*. But it can move to a higher-energy, less-stable level, or shell, by absorbing energy. This higher-energy, less-stable state is called the electron's *excited state*.
- After it's done being excited, the electron can return to its original ground state by releasing the energy it has absorbed.
- Sometimes the energy released by electrons occupies the portion of the *electromagnetic spectrum* (the range of wavelengths of energy) that humans detect as

visible light. Slight variations in the amount of the energy are seen as light of different colors.



Ground and excited states in the Bohr model.

Bohr found that the closer an electron is to the nucleus, the less energy it needs, but the farther away it is, the more energy it needs. So Bohr numbered the electron's energy levels. The higher the energy-level number, the farther away the electron is from the nucleus — and the higher the energy.

Bohr also found that the various energy levels can hold differing numbers of electrons: energy level 1 may hold up to 2 electrons, energy level 2 may hold up to 8 electrons, and so on.

The Bohr model works well for very simple atoms such as hydrogen (which has 1 electron) but not for more complex atoms.