What is an Atom?

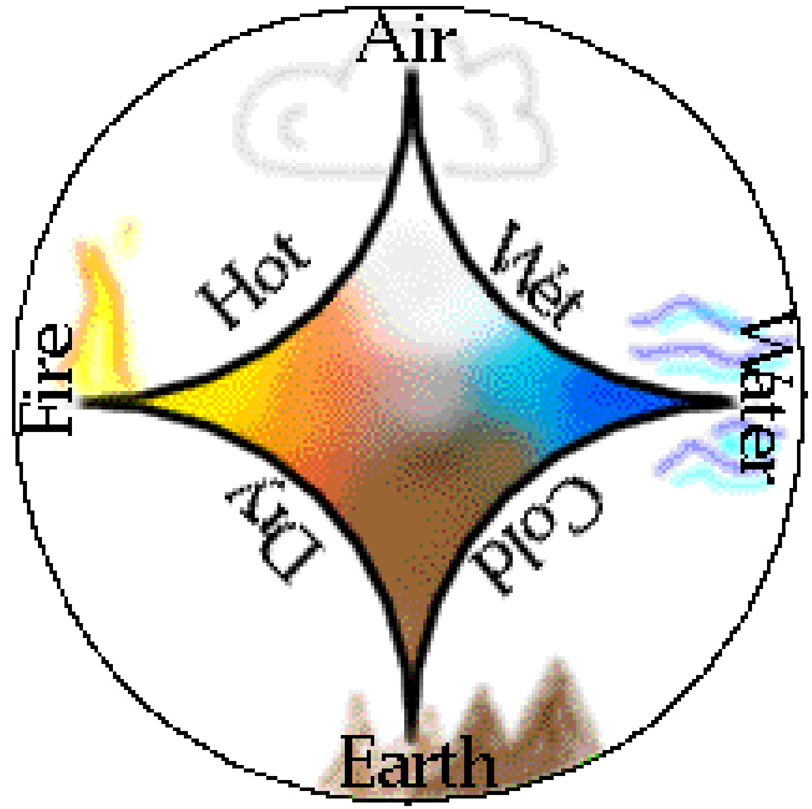
Advanced/Standard Chemistry
Unit 6
Module 3

Module Concepts

- How has our concept of the atom evolved?
- What scientists have contributed to our knowledge of the atom?
- What experimental data supports the various models of the atom?

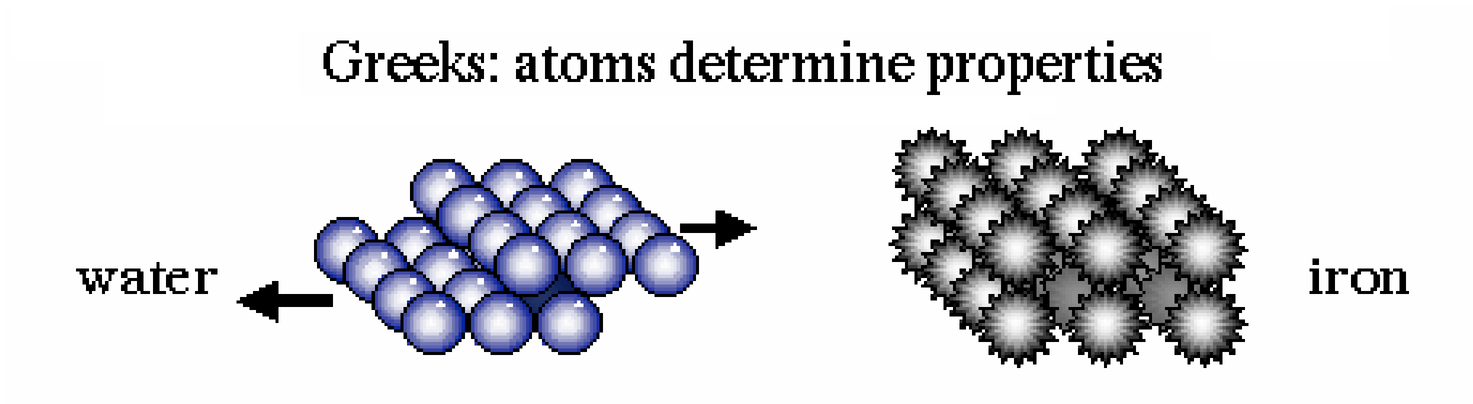
History of the Atomic Theory

- Around 400 BC, early Greek philosophers suggested that all matter is composed of one of four fundamental substances, or elements: earth, air, water, and fire.



It all begins…..

- Between 300 and 400 BC, Greek philosophers Leucippus and Democritus were among the first to propose the idea that all matter consists of tiny, indivisible particles called atoms. They have no experimental evidence to back up their claims.

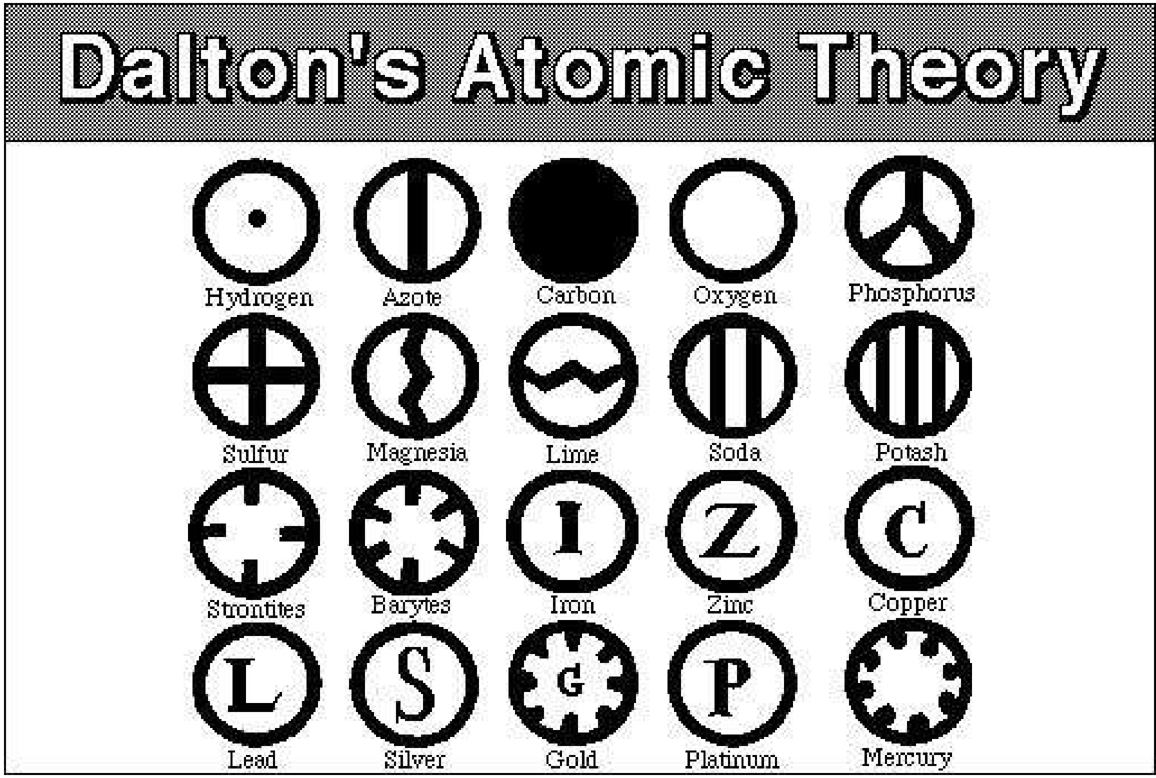


- In the late 17th century (1600s), a chemist named Robert Boyle proposed than an element is a substance that could not be further broken down by chemical means.
- We still use his definition today.

- Later, a scientist by the name of John Dalton, proposed a new theory on the nature of atoms, which became known as Dalton’s Atomic Theory. Though exceptions have been discovered, the main tenets of the theory remain intact.
- Dalton’s Atomic Theory was the first comprehensive description of the behavior of all matter.

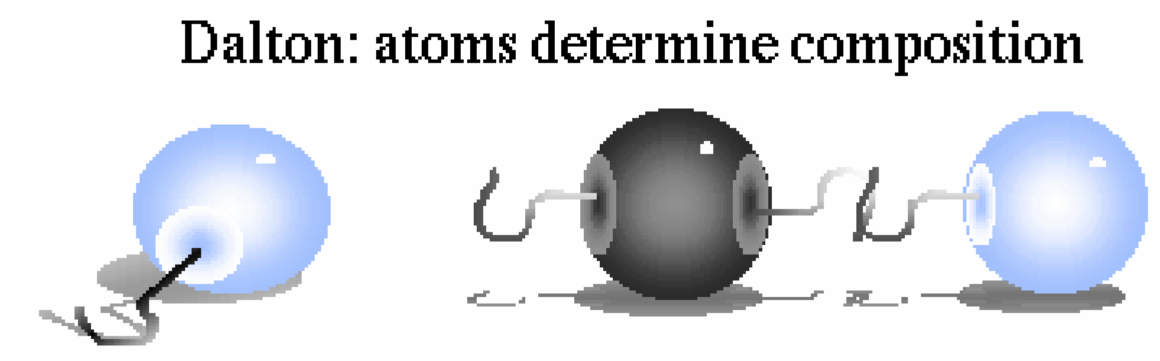
Dalton’s Atomic Theory

- Elements are made of tiny particles called atoms.
- All atoms of a given element are identical. (They didn’t know about isotopes in his day!)
- The atoms of a given element are different from those of any other element.



Dalton's Atomic Theory - continued

- Atoms of one element can combine with atoms of other elements to form compounds. A given compound always has the same relative numbers and types of atoms.
  - i.e. water always consists of hydrogen and oxygen in a 2:1 ratio
- Atoms are indivisible in chemical processes. That is, atoms are never created or destroyed in chemical reactions. A chemical reaction simply changes the way that atoms are grouped together.

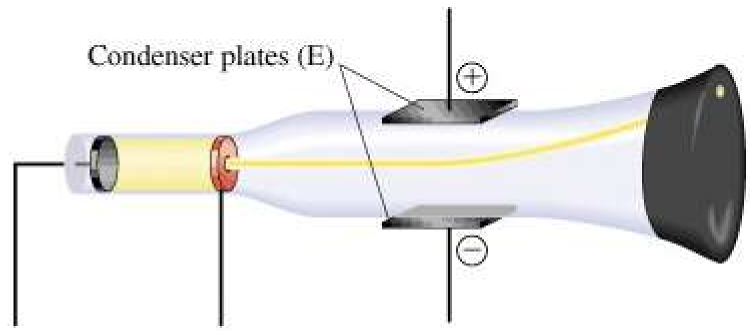


Dalton’s Atomic Model

- Dalton’s model of the atom was of a hard, immutable sphere that was the smallest piece of matter. It is sometimes referred to as the billiard ball model of the atom.

The First Subatomic Particle - Experiments Lead to the Discovery of the Electron

- JJ Thomson's cathode ray experiments (1890s)
  - Proved the existence of negatively-charged particles associated with an atom (aka electrons).
  - As a result, he proposed the "Plum Pudding" model for the atom, suggesting negatively-charged particles embedded in a ball of positive charge.



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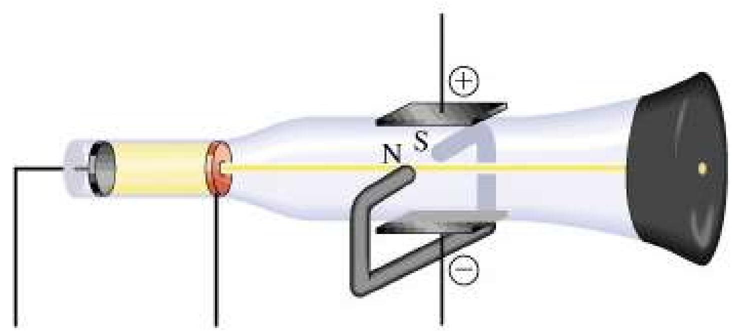

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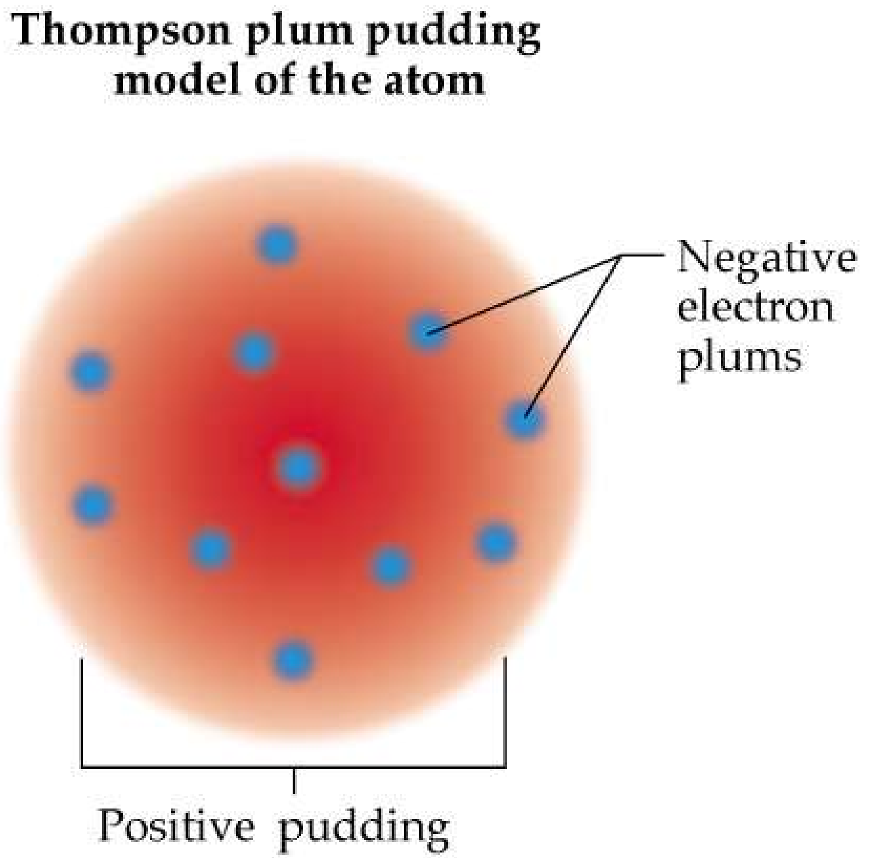
Modeling the Atom - Models Change as New Information is Gathered!



Thomson vs. Dalton

Dalton

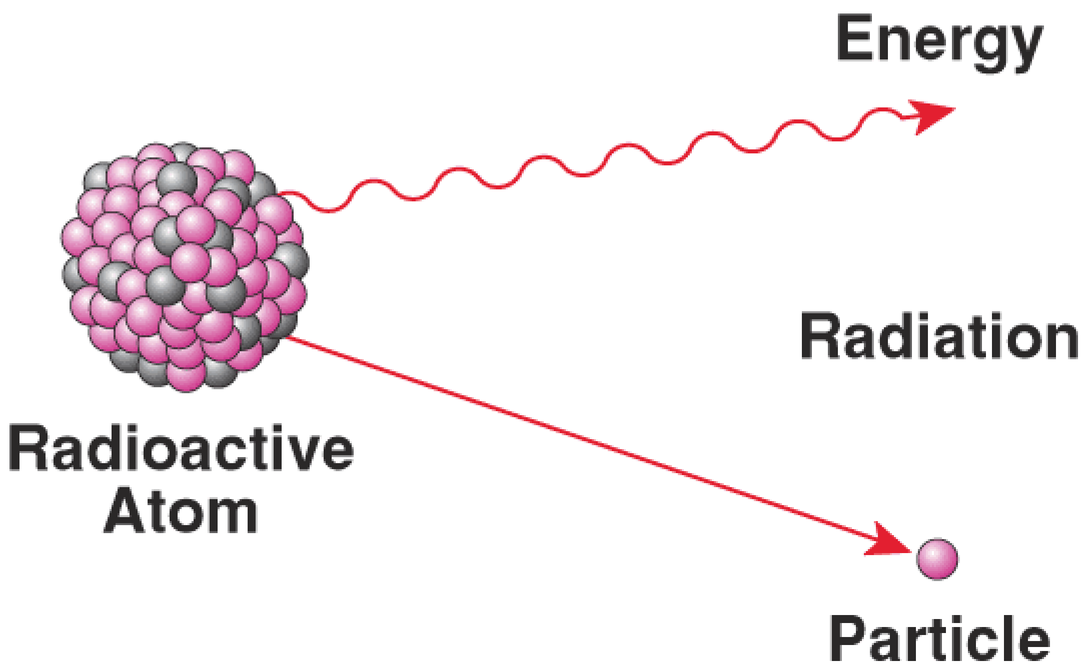
- Atom small, hard, indivisible
- Atom contains nothing smaller
- No subatomic particles
- Billiard ball

Thomson

- Atom consists of smaller particles
- Particle within atom is negatively charged
- Negative particles embedded within cloud of positive charge
- Plum Pudding

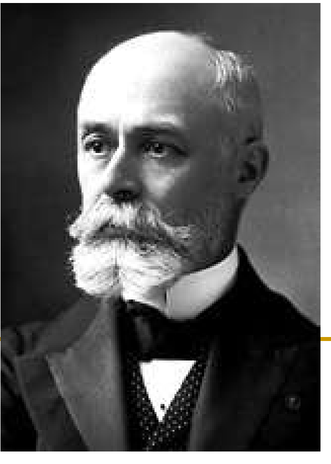
Becquerel's Experiments

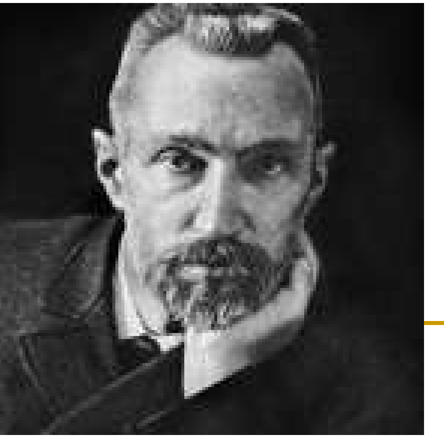
- Henri Becquerel discovered radioactivity when he was working with a sample of uranium.
  - Radioactivity is the spontaneous emission of various, specific particles, from unstable nuclei.



Radioactivity

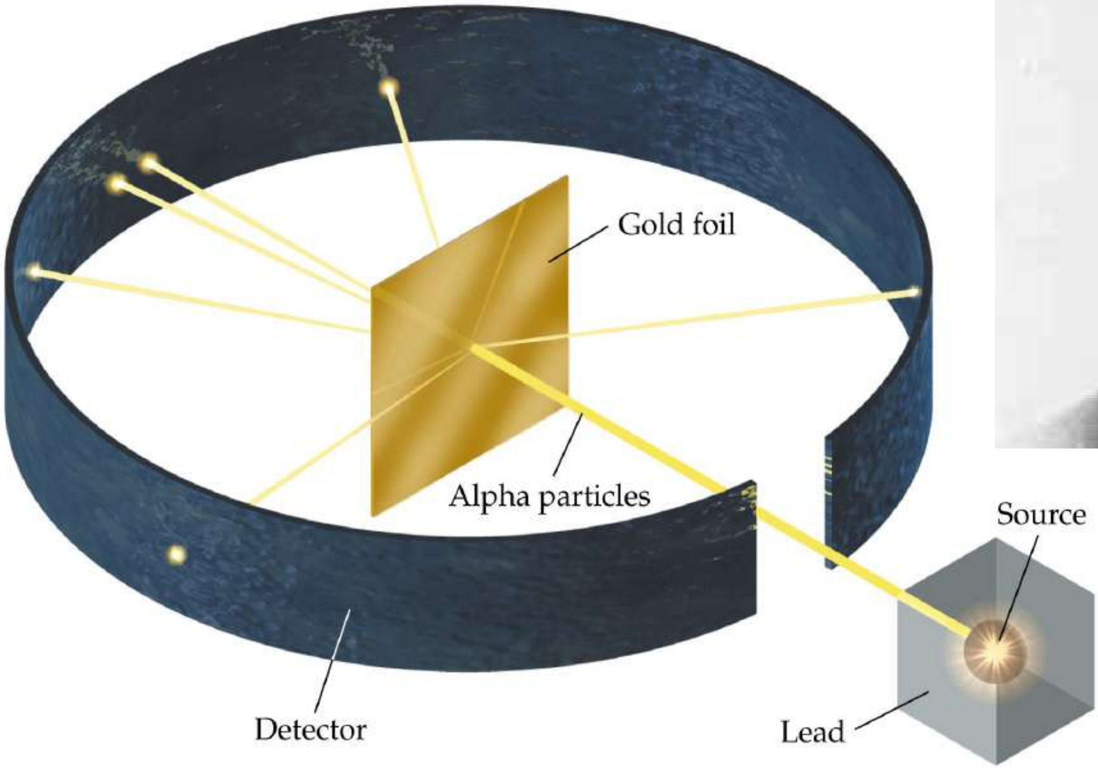
- At the time, it was unknown that atoms could undergo change; these types of particles were also unknown. Marie and Pierre Curie discovered at least four radioactive metallic elements through their research with Becquerel.
- In 1903, he, along with Marie and Pierre Curie, shared the Nobel Prize in Physics in recognition for their collaborative work on radioactivity.





Rutherford’s Experiments

- In 1911, Ernest Rutherford (a former student of J.J. Thomson) and his associates performed an experiment known as the gold foil experiment.
- In this experiment, positively charged alpha particles (helium nuclei released by radioactive samples of polonium) were fired at a thin sheet of gold foil. Most of these particles passed through the foil. However, a few bounced back at an angle.


Gold foil
Alpha particles
Source
Detector
Lead

Rutherford - Atomic Nucleus

- Rutherford concluded that the deflection of alpha particles could be explained if the majority of the atom's positive charge, as well as its mass, were concentrated within a small core at the center of the atom. He therefore proposed the existence of the atomic nucleus (Latin for "little nut"), a tiny, but dense region of the atom containing all of the positive charge of the atom. The nucleus occupies little space, but most of the mass of the atom.

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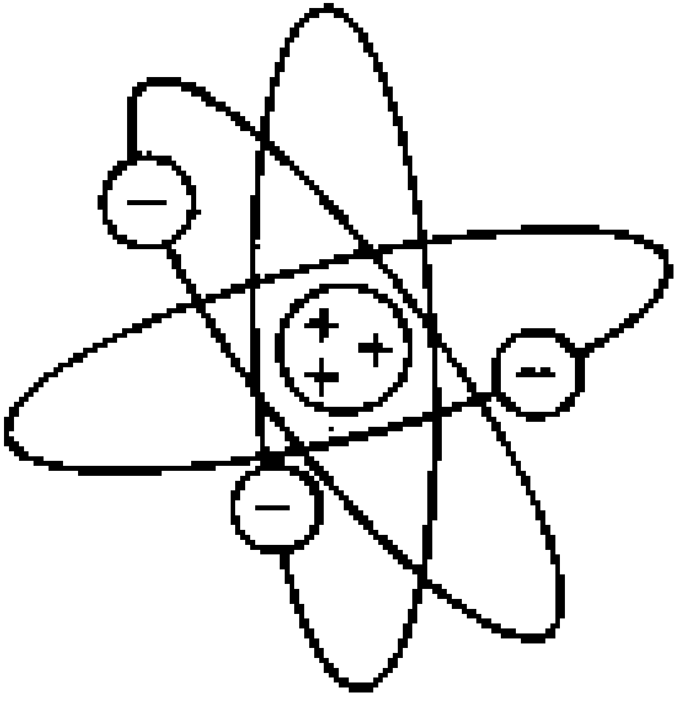
Modeling the Atom - Revisions

- Rutherford's Planetary Model

Later, Rutherford proposed that the electrons discovered by Thomson circulated around this atomic nucleus like planets revolve around the sun. Hence, his model is sometimes referred to as the planetary model of the atom.



Thomson vs. Rutherford

Thomson

- Positive charge dispersed throughout atom in “cloud”
- Negatively charged electrons (particles) embedded within positive charge
- Plum Pudding model

Rutherford

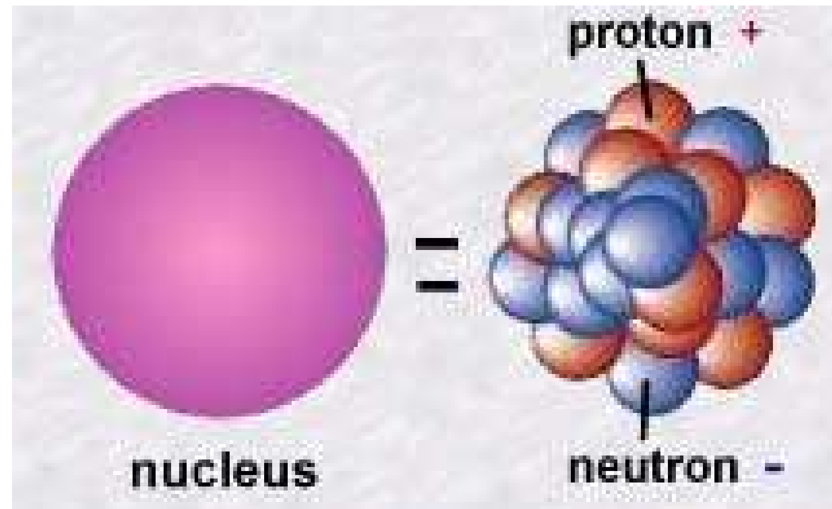
- Positive charge concentrated in nucleus
- Electrons orbit nucleus like planets around the sun
- Nucleus contains most of mass of atom but little volume of atom
- Planetary model

Moseley's Contribution - Atomic

- In 1913, a student of Rutherford, Henry Moseley, is given credit for recognizing that atoms of an element contain a unique, positive charge within the atomic nucleus.
- This discovery led to the idea that one element can be differentiated from another by the amount of positive charge within the nucleus.
- This brought about the concept of atomic number, the number of protons located in the nucleus of the atom.

James Chadwick - the Neutron

- Following up on Rutherford's predictions of a different, neutral particle in the nucleus of an atom, Chadwick was the first to prove the existence of a neutron in 1932.



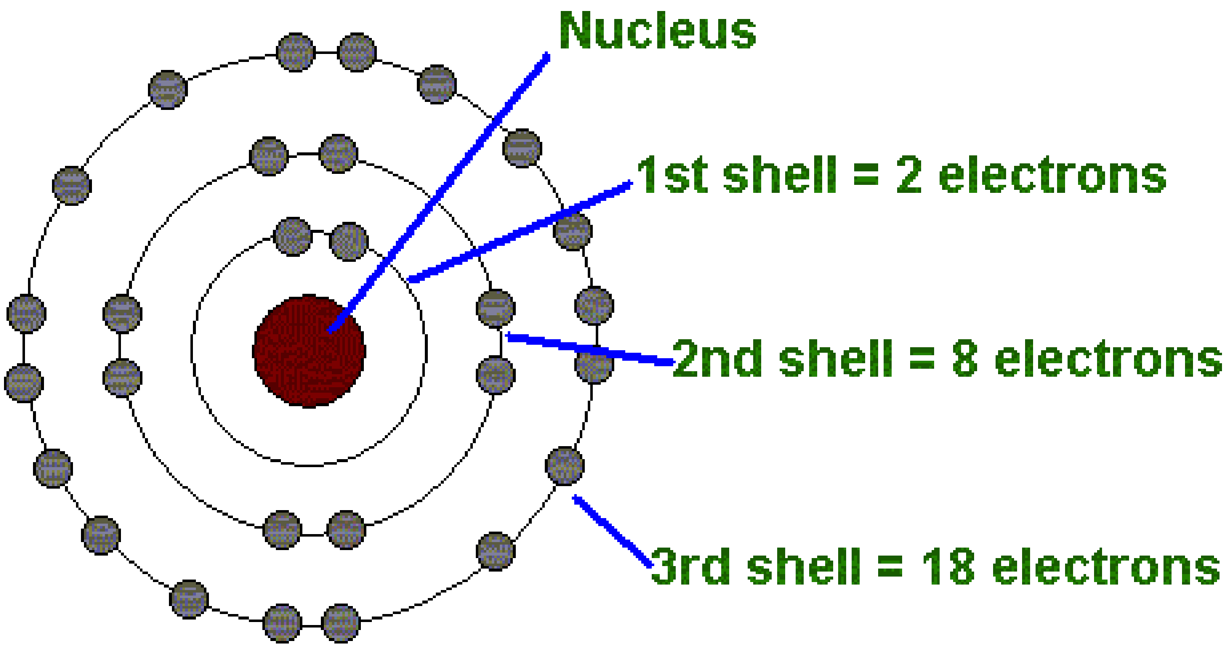
The Neutron - Nuclear Stability

- This discovery explained why the nucleus, with a strongly positive charge, did not fly apart, since like charges repel. The neutrons serve as a buffer, allowing protons to be packed tightly together in a small space.

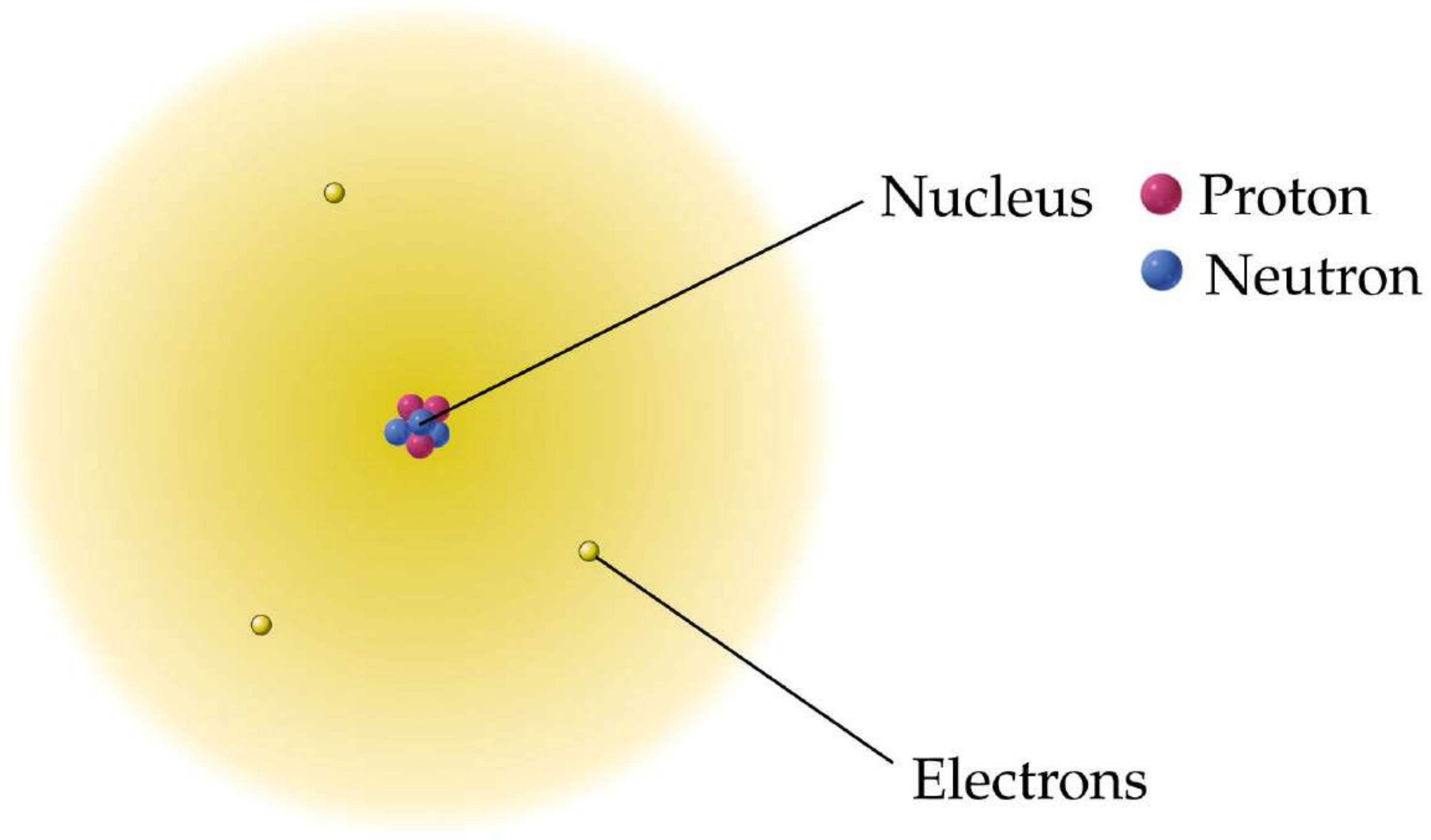
Niels Bohr - Electron Shells

- Drawing upon the works of Max Planck (quantization of energy), Einstein (the photoelectric effect), and Arthur Compton (dual nature of light), Bohr proposed that the energy of electrons must be quantized.
  - Electrons must exist only in certain orbits, which correspond to a specific amount of energy.
  - These are known as “orbits” or “shells” and can be represented by the principle quantum number n (n = 1, 2, 3, etc).

Modeling the Atom - Revised Again! Bohr's Electron Shell Model



- Quantum Mechanical Model (modern model)



- The electron cloud model (quantum mechanical model) takes into account the dual nature of the electron, which has both wave and particle tendencies.

Atomic Models – A Historical Summary