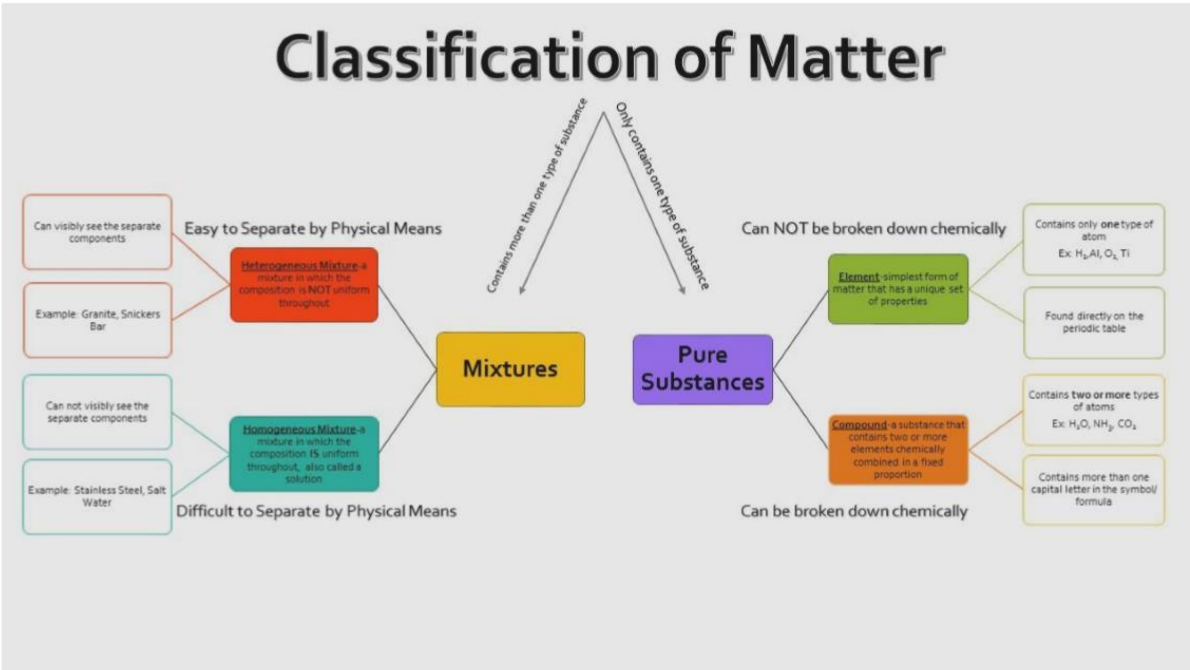
Matter

Chemistry is the study of matter. What it is, what is it made up of and how does matter react with other matter. Matter is the "stuff" that makes up the whole universe. It's the stuff that takes up space and has mass. Matter is measurable, and matter reacts in predictable ways that we will be learning about all year.

Classifying Matter



The simplest forms of matter are the **elements** which are listed in the periodic table of elements. Elements are the unique types of matter that cannot be broken down into simpler substances by any chemical or physical process. Examples include mercury, iron, carbon, and uranium. The smallest part of an element is called an atom.

Each element on the periodic table has unique properties that can be measured by us in class, or by scientists. Each element reacts in ways that are known, and which can be relied upon. We will learn later in the year how the atoms of certain elements can chemically combine, or bond, with other atoms to form new substances called **compounds**. These new substances have their own measurable properties which are different from the properties of the atoms that make them up. Compounds can only be broken back down into elements by chemical means, usually requiring energy as well.

Pure substances are types of matter made up of only one type of particle. Examples include elements which are each made up of only one kind of atom. Another example are the compounds. Compounds are made up of a specific ratio of at least two different kinds of atoms. Examples include pure water (H_2O), or glucose ($C_6H_{12}O_6$).

Pure substances are always the same throughout, which is called homogeneous. The properties of the elements are always the same in every sample, and within any one sample. All samples of pure water have the same density (for example), and all of the properties water has are the same for all samples of pure water.

Matter can be chemically combined into compounds, or just mixed together, into **mixtures**. A mixture is a physical blend of pure substances. Two or more elements can be mixed, two or more compounds can be mixed, or elements and compounds together can be mixed. Mixtures have no definite ratio of the component parts like compounds have. Because of this, mixtures are not always homogeneous, they can also be heterogeneous, or different throughout.

Mixtures are just stirred up, and the pure substances that make them up keep their properties. No new substances are formed, rather there is just a rearrangement of the atoms or particles. Compounds are new pure substances, with new properties. Since these mixtures are just physical blends, they can be separated easily, by physical means (no chemical reactions required). The processes used to separate these mixtures work because they take advantage of differences in certain physical properties of the parts of the mixture. Here are several examples…

Physical and Chemical Changes

Know the difference between physical and chemical changes.

A physical change does not result in a new substance being created which means the composition of the substance DOES NOT CHANGE. Examples of physical changes are phase changes, dissolving a solid substance in a liquid, changing the shape or size of a substance, etc.

A chemical change creates a new substance as the composition changes of the original substances. A match burning is a chemical change as the substances of the wood combine with oxygen to create new substances such as the gas CO_2.

Historical Development of the Atom

Dalton model (also called the "hard spherical model") in 1800s:

- Dalton showed that matter is made of particles that are different for each element and cannot be divided into smaller particles. These particles were called "atoms".
- Dalton stated that each element has unique atoms that are different in size and shape from the atoms of other elements.
- Dalton showed that atoms combine in unique proportions to produce compounds. For example, water is made of two atoms of hydrogen and one atom of oxygen. Hydrogen peroxide (used in lab) is made of two hydrogen atoms and two oxygen atoms.

Thomson Model in early 1900s:

- Atom is a solid particle with negative charged electrons inside with a positive solid material in between the electrons. Think of the atom as a chocolate chip cookie where the electrons are the "chips" and the solid positive substance in between the electrons is like the dough between the chips. The key discovery was the existence of negative charged electrons inside the atom. Since the atom is neutral, Thomson believed that there must be a positive charge inside the atom to balance the negative charge of the electrons.

Rutherford Model in early 1900s:

- A dense positive center of the atom called the nucleus contains positive particles called protons and negative electrons outside the nucleus moving in empty space

Rutherford Gold Foil Experiment and Conclusions

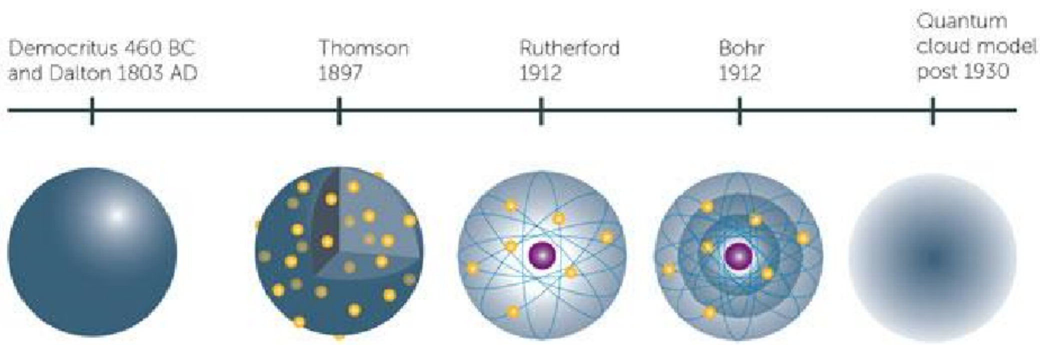
- Dense nucleus with a positive charge
- Most of the volume of the atom is empty space. Volume is determined by the outer boundaries of how far the electrons can travel.
- Electrons move around nucleus in empty space
- Particles in the nucleus with a positive charge are called protons. Each proton has a 1+ charge.
- The number of protons in the nucleus determines the type of element.

Bohr Model (also called the "electron shell model") in early 1900s: Nucleus of the atom containing protons with electrons moving in empty space with specific principal energy levels (also referred to as shells).

Modern Model- AKA Wave Mechanical Model/ Quantum Mechanical Model/ Electron-Cloud Model:

- Electrons are in orbitals outside the nucleus with each orbital representing the **region of space most likely to find an electron**.
- This region of space is also called an "electron cloud".
- The electrons are located outside the nucleus of the atom.
- This is the most current view of the model of the atom.
- It is important to realize that this model does not state that the electron moves in a circular or elliptical orbit around the nucleus. Orbit=Bohr Model, Orbital=Electron-Cloud Model

Summary of the Atom's Historical Development



Subatomic Particles (Parts of the Atom)

- Electron (1- charge & mass = 1/1840 of proton)
- Proton (1+ charge & mass approximately equal to 1 atomic mass unit)
- Neutron (zero charge & mass approximately equal to 1 atomic mass unit)
- The Regents Exam states that the proton and electron have the "same magnitude but opposite charge". Students must understand the word magnitude and not think that the negative charge of the electron means the charge is less than the positive charge of the proton. They have the same magnitude of charge but have opposite charges.
- Protons located inside the nucleus
- Neutrons located inside the nucleus
- The nucleus must always have a positive charge equal to the number of protons.
- Electrons located outside the nucleus
- Almost all the mass of the atom is in the nucleus (protons plus neutrons)
- In chemistry we ignore the mass of the electron since it is so small (1/1840 mass of the proton or neutron)
- Atomic number is equal to the number of protons
- Element is determined by number of protons. For example: oxygen has 8 protons. No other atom of any element has 8 protons. Chlorine has 17 protons. Potassium has 19 protons.

Mass Number and Isotopes

- Mass number = # protons + # neutrons
- Isotopes are atoms of the SAME ELEMENT (same # of protons in the nucleus) that have different number of neutrons only. For example, chlorine has two isotopes where the mass number is 35 and 37. This means these two atoms have the same number of protons (equal to 17), but different number of neutrons. Since mass number = #protons + # neutrons, then one atom has 18 neutrons (18 = 35-17) and the other 20 neutrons (20=37-17).
- Average Atomic Mass is weighted average of mass of ALL THE NATURALLY OCCURING isotopes. SOME ELEMENTS MAY HAVE 2, 3, 4 OR MORE ISOTOPES.
- Weighted average is used to take into account the percentage that each different isotope exists naturally. This percentage is referred to as "abundance".

Example of calculating atomic mass: What is the atomic mass of an element X that has the following "abundance" of each isotope: 20% of ^{14}X that has a mass of 14.025 atomic mass units and 80% of ^{17}X that has a mass of 17.125 atomic mass units?
Solution: Atomic mass = (0.20 x 14.025) + (0.80 x 17.125) = 2.805 + 13.700 = **16.505amu**

Isotope Examples: potassium-39 OR ^{39}K. Remember that the number represents the "mass number"

Example of Questions on Isotopes:
What is the mass number of an atom with 17 neutrons and 20 protons?
How many neutrons in gold-198?
How many neutrons in ^{226}Ra?

Electrons

Principal energy levels (also called "shells") are shown as circles around the nucleus. **THE FURTHER A CIRCLE IS FROM THE NUCLEUS, THEN THE ELECTRON HAS MORE ENERGY TO BE FARTHER AWAY FROM THE POSITIVE ATTRACTION OF THE NUCLEUS.**

- All electrons in the same energy level are on the same principal energy level
- The higher the energy level, the farther away the electrons are from the nucleus, and the more energy they have.

Electron Configuration

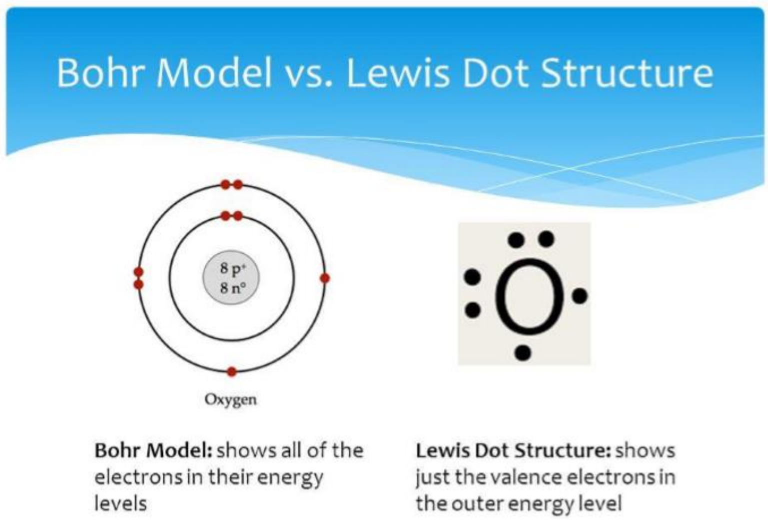
- Ground State Configuration in Periodic Table (Reference Table)
- Excited State Configuration is different from the configuration in the Reference Table
- Example: Potassium Ground State = 2-8-8-1
- Example: Possible Potassium Excited State = 2-8-7-2.
- Electrons absorb energy to move to a higher energy level to become excited. In the Excited State for Potassium shown above, an electron moved from the 3rd principal energy level to the 4th principal energy level by absorbing energy.
- Max # of electrons in first energy level is **2** and in second energy level is **8**.

Valence Electrons

- Valence electrons are the electrons in the outermost Principal Energy Level (outer "shell")
  - Example: Potassium Ground State = 2-8-8-**1**

- Valence electrons are very important since it is the valence electrons that determine the chemical properties of an element.

Bohr Diagram and Lewis-Dot Structure Representations of Electrons in Atoms



Spectral Lines (Electron Emission Spectra)

- Electrons moving from a higher energy level to a lower level release energy
- Energy released is in the form of **light**
- Energy of light photon is determined by Principal Energy Level changes when electron returns to a lower energy level
- Each element has unique spectral lines that represent how electrons return to lower energy levels from excited states and release unique photons of liqht with different colors.
- An element can be identified by its unique spectral lines, similar to how a person can be identified by their fingerprints.
- The energy of light is determined by the "wavelength" of the wave of light. The longer the wavelength, the lower the energy. The shorter the wavelength, the higher the energy.