Basic Concepts About Matter
- Chemistry is the study of the properties and changes of matter
- What exactly is matter?
  - Matter is anything which has mass and takes up space (volume)
  - Examples of matter:
    - Sand (a solid)
    - Water (a liquid)
    - Air (a mixture of gases)

How do we learn chemistry?
- Chemistry is an empirical science, meaning that it is based on the results of experiments.
- In the lecture we will study theories and laws based on many years of observations and experiments.
- In the laboratory we will verify many of these principles.

A Conceptual Approach
- During this course, we will focus on the fundamental concepts which define chemistry.
- Specifically, we will often look at matter at the smallest level (the submicroscopic level) to try to reason why matter behaves the way it does on a larger, or macroscopic, scale.
- This is an essential skill for the aspiring chemist; a good imagination is all you need to develop it!

Atoms: A Brief Overview
- Atoms are the most fundamental units of matter we consider in this course
- All matter which we encounter in our daily lives contains an extremely large number of these tiny particles
- There are many different types of atoms
  - Some common examples are hydrogen, oxygen, gold, and sodium
- We will look closely at the structures of atoms at a later point in this course

Molecules
- Two or more atoms may join together to form a molecule
- Molecules are held together by bonds
  - Specifically, these are called covalent bonds; more on these later!
- A diatomic molecule is made up of exactly two atoms (which may be the same or different)

Molecules
Physical States of Matter
- There are three common physical states of matter which we will consider in this class
  - Gases
  - Liquids
  - Solids
- We compare the three states by asking two questions
  - Does the substance have a definite shape, or does it take the shape of its container?
  - Does the substance have a definite volume?

Solids
- Solids have a definite shape
  - They do not assume the shape of their container
- Solids have a definite volume
- The particles making up a solid
  - are close together
  - do not move about, but vibrate in place
  - tend to form organized patterns
Liquids
- Liquids have an indefinite shape
  - They take the shape of their container
- Liquids have a definite volume
- The particles making up a liquid
  - are fairly close together, but not to the same extent as solids
  - move freely throughout the liquid
  - are not organized in any particular pattern

Gases
- Gases have an indefinite shape
  - Like liquids, they take the shape of their container
- Gases have indefinite volume
- The particles making up a gas
  - are generally far apart from one another
  - move freely throughout their container in a random fashion

Classification of Matter
- We classify matter as either a pure substance or a mixture
- There are two types of pure substances
  - Elements
  - Compounds
- There are two types of mixtures
  - Homogeneous mixtures
  - Heterogeneous mixtures

Elements
- A pure sample of an element contains only one type of atom
  - A sample of gold—an element—contains only gold atoms
  - Helium contains only helium atoms
- There are over a hundred known elements
- Each element is assigned a name and a symbol
  - Each symbol consists of one to three letters
  - The first letter of the symbol is always capitalized; any other letters are always written in lowercase
- The symbols (and occasionally the names) are catalogued on the Periodic Table of the Elements

Some Atomic Symbols
- H: Hydrogen  O: Oxygen
- C: Carbon  N: Nitrogen
- Na: Sodium  Cu: Copper
- Cl: Chlorine  K: Potassium

- Note that some of these symbols are unusual!

Elements
- Some elements are generally only found as diatomic molecules
- We will call these seven elements the diatomic elements

Be sure you know these!
Elements and Symbols You Must Know

You must memorize the symbols and names (with the correct spelling) for each element listed on this periodic table. I recommend making flashcards to help you in this.
Compounds
- Atoms come together in whole number ratios to form compounds.
- The chemical formula lists the ratio of these elements in the compound.
  - Each unit of water contains two hydrogen atoms and one oxygen atom $\rightarrow$ H$_2$O
  - Other examples: NaCl, SiO$_2$, C$_6$H$_{12}$O$_6$
  - This formula/ratio is always the same for a chemical compound
  - Different compounds may have the same formula.
  - The compound is said to have a definite composition

Mixtures
- The composition of a mixture is not fixed.
  - Consider salt water, a mixture of H$_2$O and NaCl.
    - Is salt water always found in the same proportion? The same atom-to-atom ratio?

Mixtures can be classified into two types:
- Homogeneous mixtures have all parts in the same state (gas, liquid or solid) and all parts must be mixed together.
  - If the parts of the mixture are visually inseparable, we will call the mixture homogeneous.
- Heterogeneous mixtures are simply those which are not homogeneous.

Separations
- Mixtures can be separated by physical methods
  - A heterogeneous mixture of coffee grounds and water can be separated by filter paper
  - The water can be removed from a salt water solution (a homogeneous mixture) by boiling the water off. The salt will remain in the container.
- Compounds can only be separated into their individual elements by chemical means (i.e. through the result of a chemical reaction)

Mixtures
- Ex. Are each of these mixtures homogeneous or heterogeneous? Why?
  - Vodka (a mixture of water and ethyl alcohol)
  - Cheerios in milk
  - A mixture of oil and water
  - A salt water solution
  - Note that the term solution is often used to refer to homogeneous mixtures, especially for compounds dissolved in water.
Classification Problems
- Classify each of these as an element, a compound, a homogeneous mixture, or a heterogeneous mixture.
  - Tap water

- Steel (an alloy of several metals)
  - Note that alloys can be mixed in different proportions.

- Helium

- Mud

- Carbon dioxide

Properties of Matter
- We can describe matter in two ways:
  - By its chemical properties, which describe how a type of matter interacts (or “reacts”) with another type of matter.
    - For example, hydrogen is able to react with oxygen to form water. Helium reacts with virtually nothing.
  - By its physical properties, which include all non-chemical properties.
For example, water is a liquid at room temperature, freezes at 0 °C, has a density of 1.0 g/mL, and is both clear (we can see through it) and colorless.

Changes of Matter
- Common changes of matter are described in essentially the same way as properties are
- A chemical change is a change which involves a chemical reaction
  - Bonds are formed and/or broken in a chemical change
  - The chemical substances you end with are fundamentally different than what you began with
- A physical change is a change which does not involve a chemical reaction
  - All changes of state of a given substance are physical changes
    - Examples include ice melting and liquid water boiling

Classify each change as either a physical change or a chemical change
- Gasoline evaporates off of the ground
- A glass vase is shattered
- Sodium reacts with chlorine, forming sodium chloride
- Dry grass burns in a large fire