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)

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!
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: $\text{H}_2\text{O}$
  - 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