INTRODUCTION TO CHEMISTRY

- Chemistry is the science that deals with the **materials** of the universe, and the **changes** they undergo.

- **Materials** of the universe can be of several forms:
  
  **Gas:** air, oxygen
  
  **Liquid:** water, gasoline, vinegar, orange juice,
  
  **Solid:** rocks, charcoal, table salt, sugar, wood, baking soda

- Some examples of **changes**:
  
  **Burning of charcoal**
  
  charcoal + oxygen $\rightarrow$ carbon dioxide

  **Burning of gasoline**
  
  gasoline + oxygen $\rightarrow$ carbon dioxide + water vapor

  **Fermentation of grape juice**
  
  glucose $\rightarrow$ ethyl alcohol + carbon dioxide
  
  (in water) (in water)

  **Souring of wine**
  
  ethyl alcohol + oxygen $\rightarrow$ acetic acid
  
  (in water) (from air) (in water)
SCIENTIFIC METHOD

- is a general, overall philosophy of approach to the study of nature
- a formal statement of the steps that any of us follow as we **logically** approach a problem

- **EXPERIMENTS**
  - Observation of natural phenomena carried out in a controlled manner so that the results can be duplicated and rational conclusions obtained

- **RESULTS**

- **HYPOTHESIS**
  - A tentative explanation of some regularity of nature

- **FURTHER EXPERIMENTS**
  - devised based on hypothesis

- **NEGATIVE RESULTS**
  - Lead to modification or rejection of hypothesis and formulation of new hypothesis

- **POSITIVE RESULTS**
  - Support hypothesis

- **THEORY**
  - A tested explanation of basic natural phenomena
  - Follows after results consistently support a hypothesis

- **FURTHER EXPERIMENTS**

- **NATURAL LAW**
  - A statement that summarizes facts that come from many experiments
LAW OF CONSERVATION OF MASS

Antoine Lavoisier (1743-1794)
- studied chemical changes
- pioneered the use of balances in chemical research
- weighed the substances before and after a chemical change
- studied the process of burning (combustion)

SHOWED THAT WHEN A MATERIAL BURNS, A COMPONENT OF AIR (HE CALLED IT OXYGEN) COMBINES CHEMICALLY WITH THE MATERIAL.

Examples:
1. Mercury is heated in air to form mercuric oxide

   \[
   \begin{align*}
   \text{Mercury} & \quad + \quad \text{Oxygen} & \quad \rightarrow & \quad \text{Mercuric OXide} \\
   200.6 \text{ g} & \quad \ ? & \quad \rightarrow & \quad \text{more or less than 200.6 g} \\
   200.6 \text{ g} & \quad \ ? & \quad \rightarrow & \quad 216.6 \text{ g} \\
   200.6 \text{ g} & \quad + \quad 16.0 \text{ g} & \quad \rightarrow & \quad 216.6 \text{ g}
   \end{align*}
   \]

2. When sugar is heated it forms carbon and water vapor. Will the carbon weigh more or less than the sugar?

   \[
   \begin{align*}
   \text{sugar} & \quad \rightarrow & \quad \text{carbon} & \quad + \quad \text{water (g)} \\
   34.2 \text{ g} & \quad 14.4 \text{ g} & \quad \ ? \\
   34.2 \text{ g} & \quad 14.4 \text{ g} & \quad 19.8 \text{ g}
   \end{align*}
   \]

THE TOTAL MASS REMAINS CONSTANT DURING A CHEMICAL CHANGE

MASS vs. WEIGHT

<table>
<thead>
<tr>
<th>MASS</th>
<th>WEIGHT</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The quantity of matter in an object</td>
<td>- The force of gravity exerted on an object</td>
</tr>
<tr>
<td>- Independent of location on earth</td>
<td>- Depends on location on earth (the closer to the center of the earth, the more the object weighs)</td>
</tr>
<tr>
<td>- Measured in grams (g) or kilograms (kg)</td>
<td>- Measured in Newtons (N)</td>
</tr>
<tr>
<td>- Measured on a balance (massing)</td>
<td>- Measured with a spring scale (weighing)</td>
</tr>
<tr>
<td>- Commonly used in chemical laboratory</td>
<td></td>
</tr>
<tr>
<td>- Sometimes mistakenly referred to as weight</td>
<td></td>
</tr>
</tbody>
</table>
## PHYSICAL & CHEMICAL PROPERTIES

- The characteristics of a sample are its properties.

<table>
<thead>
<tr>
<th>PHYSICAL PROPERTIES</th>
<th>CHEMICAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>- A property that can be observed without changing the chemical identity of the sample of matter</td>
<td>- A property that refers to the ability of a substance to form different substances</td>
</tr>
</tbody>
</table>

**Examples:**
- Physical state (solid, liquid, gas)
- Odor
- Color
- Melting point
- Boiling point
- Density
- Specific heat

**Examples:**
- Charcoal burns in air
- Iron rusts
- Grape juice ferments
- Wine sours
- Alcohol is flammable

**Examples:**
Identify each of the following properties as physical or chemical:

1. Oxygen is a gas
2. Helium is unreactive
3. Water has a high specific heat
4. Gasoline is flammable
5. Sodium is soft and shiny
PHYSICAL & CHEMICAL CHANGES

<table>
<thead>
<tr>
<th>PHYSICAL CHANGES</th>
<th>CHEMICAL CHANGES (REACTIONS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• A change in the form of matter but not in its chemical identity</td>
<td>• A change in which one or more kinds of matter are transformed into a new kind of matter or several new ones</td>
</tr>
</tbody>
</table>

Examples:
- Freezing of water
- Boiling of water
- Melting of ice
- Evaporation of alcohol
- Sublimation of dry ice

Examples:
- Souring of wine
- Rusting of iron
- Burning of alcohol
- Explosion of a firecracker
- Electrolysis of water

Physical Changes

Chemical Changes

Examples:
Identify each of the following changes as physical or chemical:

1. Cooking food
2. Mixing sugar in tea
3. Carving wood
4. Burning gas
5. Food molding
I. CLASSIFICATION OF MATTER

I. CLASSIFICATION OF MATTER BY PHYSICAL STATE

<table>
<thead>
<tr>
<th>Solids</th>
<th>Liquids</th>
<th>Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed volume</td>
<td>Fixed volume</td>
<td>No fixed volume</td>
</tr>
<tr>
<td>Fixed shape</td>
<td>No fixed shape</td>
<td>No fixed shape</td>
</tr>
<tr>
<td>Maintain their shape</td>
<td>Flow</td>
<td>Flow</td>
</tr>
<tr>
<td>Are rigid</td>
<td>Are fluid</td>
<td>Are fluid</td>
</tr>
<tr>
<td>Incompressible</td>
<td>Incompressible</td>
<td>Compressible</td>
</tr>
</tbody>
</table>

NOTE:
1. The three forms of matter (solid, liquid, gas) are referred to as states of matter
2. This classification is not very meaningful, since the majority of the different forms of matter may exist in all three physical states, depending on conditions.

Example: Water can exist as:
1. Solid water (ice) at very low temperatures (below 0°C)
2. Liquid water (between 0°C and 100°C)
3. Gaseous water or water vapor (above 100°C)

The term vapor is used to refer to the gaseous state of a form of matter that exists as a solid or a liquid at room temperature (25°C)
II. CLASSIFICATION OF MATTER BY CHEMICAL CONSTITUTION

MATTER

SUBSTANCES
- Forms of matter with constant composition and fixed properties
- Can be separated by physical processes (filtration, distillation, chromatography)

MIXTURES
- Forms of matter with variable composition; Properties depend on composition.

ELEMENTS
- Substances that cannot be decomposed by any chemical reaction into simpler substances
- Examples: H, O, C, N, Na, Cl, Hg, Al, I, Au, Pb, Cu, Ag, P, He, Mg, Fe

COMPOUNDS
- Substances composed of two or more elements chemically combined
- Examples: water, sugar, carbon dioxide, ammonia, glucose, sodium chloride

HOMOGENEOUS
- (same throughout)
- Solid: bronze, brass
- Liquid: wine, vinegar
- Gaseous: air

HETEROGENEOUS
- (different throughout)
- Soil, orange juice
MEASUREMENT

- Is the comparison of a physical quantity with a unit of measurement.
  
  Example: The mass of the same penny is measured by 3 different students on the same balance:  
  \[ m_1 = 3.11 \text{ g} \quad m_2 = 3.12 \text{ g} \quad m_3 = 3.13 \text{ g} \]

  The mass of the penny is reported as: **3.12 g**
  
  we are sure of this digit  
  this digit is accurate (certain)  
  the **accuracy is ± 0.1 g**

  we are not sure of this digit  
  this digit is uncertain  
  the **uncertainty is ± 0.01 g**

  The mass of the penny should be reported as: (3.12 ± 0.01) g

  the uncertainty of the measurement  
  (normally not shown, but implied)

- The three student obtained measured values which are very close to each other.

- We say that their measurements had good **REPRODUCIBILITY** or had good **PRECISION**
**PRECISION:**
- is a determination of the reproducibility of a measurement.
- tells you how closely several measurements agree with one another.
- precision is affected by random errors.

**ACCURACY:**
- closeness of a measurement to a true, accepted value.
- is subject to systematic errors (errors which are off in the same direction, either too high or too low)

Are we confident that the correct mass of the penny is 3.12 g?
Actually the True Value of the penny is: 3.03 g

What went wrong?
- The balance may not have been zeroed,
- The pan of the balance may have been dirty?
- This measurement is badly off from the true value  Such a measurement is said to have LOW ACCURACY

**Conclusion:**
The measurement of the penny as reported (3.12 g) has: HIGH PRECISION but LOW ACCURACY  
(measured values are close to each other)  
(reported value is far off from true value)
Consider that the length of an object is measured with two different rulers:

### Millimeter Ruler

![Millimeter Ruler Diagram]

Several observers report:
- 1.25 cm
- 1.24 cm
- 1.26 cm

Length should be reported as 1.25 cm (implies ± 0.01 cm)

**NOTE:**
- The accuracy of the ruler is 0.1 cm (1 mm)
- The uncertainty of the ruler is 0.01 cm (0.1 mm)
- One must record the measured value to one more place than the scale is marked

### Centimeter Ruler

![Centimeter Ruler Diagram]

Several observers report:
- 1.3 cm
- 1.2 cm
- 1.4 cm

Length should be reported as 1.3 cm (implies ± 0.1 cm)

**NOTE:**
- Precision and accuracy of a measurement are limited by the instrument.