General Chemistry

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Chemistry is the study of matter and the changes it undergoes

1. Matter is anything that occupies space and has mass.

2. A substance is a form of matter that has a definite composition and distinct properties.
Matter

- Atom
- Element
- Compound
- Molecule
- Gas
- Liquid
- Solid
- Substance

Mixture

Two or more different compounds

Homogenous
- One phase
- Salt + water
- Solution
- N₂ + O₂ + CO₂
- Air

Heterogeneous
- Different phases
- Sand + water
- CO₂ + Water
A *mixture* is a combination of two or more substances in which the substances retain their distinct identities.

1. **Homogeneous mixture** – composition of the mixture is the same throughout.
   
   soft drink, solder

2. **Heterogeneous mixture** – composition is not uniform throughout.
   
   cement, iron filings in sand
An **element** is a substance that cannot be separated into simpler substances by **chemical means**.

- 114 elements have been identified
  - 82 elements occur naturally on Earth
    - gold, aluminum, lead, oxygen, carbon
  - 32 elements have been created by scientists
    - technetium, americium, seaborgium
# Classification of Matter

**Matter**
Anything with mass and volume.

<table>
<thead>
<tr>
<th><strong>Substance</strong></th>
<th><strong>Mixture</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Matter with constant composition</td>
<td>Matter with variable composition</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Element</strong></th>
<th><strong>Compound</strong></th>
<th><strong>Heterogeneous Mixture</strong></th>
<th><strong>Homogeneous Mixtures</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Substance made up of only one type of atom</td>
<td>Two or more elements that are chemically combined</td>
<td>Mixtures that are made up of more than one phase</td>
<td>Also called solutions. Mixtures that are made up of only one phase</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Examples</strong></th>
<th><strong>Examples</strong></th>
<th><strong>Examples</strong></th>
<th><strong>Examples</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>gold, silver, carbon, oxygen and hydrogen</td>
<td>water, carbon dioxide, sodium bicarbonate, carbon monoxide</td>
<td>sand, soil, chicken soup, pizza, chocolate chip cookies.</td>
<td>salt water, pure air, metal alloys, seltzer water.</td>
</tr>
</tbody>
</table>
Three States of Matter

Solids

Liquids

Gases

Solid examples: hat, skateboard, pencil, table, snow, bicycle, apple, computer, treehouse

Liquid examples: water in pool, milk, hot chocolate, drink, soup, rain

Gas examples: wind, air, hot air balloon, steam, fog, wind from fan
**Substance** - A material with a constant composition. NaCl, H₂O, Ne, CO₂, and O₂ are all substances, because their composition will be the same no matter where you find them. All elements and all compounds are defined as substances.

**Elements** - Any substance that contains only one kind of an atom is known as an **element**. Because atoms cannot be created or destroyed in a chemical reaction, elements such as phosphorus (P₄) or sulfur (S₈) cannot be broken down into simpler substances by these reactions.

**Example:** Water decomposes into a mixture of hydrogen and oxygen when an electric current is passed through the liquid. Hydrogen and oxygen cannot be decomposed into simpler substances.

\[
2\text{H}_2\text{O} \rightarrow 2\text{H}_2 + \text{O}_2
\]

Elements are represented by symbols. The symbol is one, two, or three letters that represent the name. It’s easier to write O than to write oxygen. It’s easier to write H than to write hydrogen. The same symbols are used for each element in all countries of the world.
A **compound** is a substance composed of atoms of two or more elements chemically united in fixed proportions.

Compounds can only be separated into their pure components (elements) by *chemical* means.

- Water ($\text{H}_2\text{O}$)
- Glucose ($\text{C}_6\text{H}_{12}\text{O}_6$)
- Ammonia ($\text{NH}_3$)
<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Name</th>
<th>Symbol</th>
<th>Name</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Al</td>
<td>Fluorine</td>
<td>F</td>
<td>Oxygen</td>
<td>O</td>
</tr>
<tr>
<td>Arsenic</td>
<td>As</td>
<td>Gold</td>
<td>Au</td>
<td>Phosphorus</td>
<td>P</td>
</tr>
<tr>
<td>Barium</td>
<td>Ba</td>
<td>Hydrogen</td>
<td>H</td>
<td>Platinum</td>
<td>Pt</td>
</tr>
<tr>
<td>Bismuth</td>
<td>Bi</td>
<td>Iodine</td>
<td>I</td>
<td>Potassium</td>
<td>K</td>
</tr>
<tr>
<td>Bromine</td>
<td>Br</td>
<td>Iron</td>
<td>Fe</td>
<td>Silicon</td>
<td>Si</td>
</tr>
<tr>
<td>Calcium</td>
<td>Ca</td>
<td>Lead</td>
<td>Pb</td>
<td>Silver</td>
<td>Ag</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
<td>Magnesium</td>
<td>Mg</td>
<td>Sodium</td>
<td>Na</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Cl</td>
<td>Manganese</td>
<td>Mn</td>
<td>Sulfur</td>
<td>S</td>
</tr>
<tr>
<td>Chromium</td>
<td>Cr</td>
<td>Mercury</td>
<td>Hg</td>
<td>Tin</td>
<td>Sn</td>
</tr>
<tr>
<td>Cobalt</td>
<td>Co</td>
<td>Nickel</td>
<td>Ni</td>
<td>Tungsten</td>
<td>W</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
<td>Nitrogen</td>
<td>N</td>
<td>Zinc</td>
<td>Zn</td>
</tr>
</tbody>
</table>
### Examples of Some Chemical Formulas

<table>
<thead>
<tr>
<th>Compound</th>
<th>Common Name</th>
<th>Chemical Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>calcium carbonate</td>
<td>chalk</td>
<td>CaCO$_3$</td>
</tr>
<tr>
<td>carbon dioxide</td>
<td>dry ice</td>
<td>CO$_2$</td>
</tr>
<tr>
<td>hydrochloric acid</td>
<td>muriatic acid</td>
<td>HCl</td>
</tr>
<tr>
<td>hydrogen sulfide</td>
<td>rotten-egg gas</td>
<td>H$_2$S</td>
</tr>
<tr>
<td>sodium hydrogen carbonate (or sodium bicarbonate)</td>
<td>baking soda</td>
<td>NaHCO$_3$</td>
</tr>
<tr>
<td>sodium chloride</td>
<td>table salt</td>
<td>NaCl</td>
</tr>
<tr>
<td>sodium nitrate</td>
<td>fertilizer</td>
<td>NaNO$_3$</td>
</tr>
<tr>
<td>sulfuric acid</td>
<td>battery acid</td>
<td>H$_2$SO$_4$</td>
</tr>
</tbody>
</table>
• Define *matter* and explain what its three states are?
• What are the common names for the three states of the compound water?
• Define pure substance and give three examples of pure substances.
• Explain the difference between *element and compound*. 
Classify the following as, a compound, an element, homogenous or heterogenous mixture or.

- a) bread
- b) orange juice
- c) exhaust from a car
- d) piece of gold
- e) water
- f) ice cream
- g) Milk
- h) Sodium chloride
General Chemistry

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A physical change does not alter the composition or identity of a substance.  

- ice melting
- sugar dissolving in water

A chemical change alters the composition or identity of the substance(s) involved.

- hydrogen burns in air to form water
Extensive and Intensive Properties

An **extensive property** of a material depends upon how much matter is being considered.

- mass
- length
- volume

An **intensive property** of a material does not depend upon how much matter is being considered.

- density
- temperature
- color
Does each of the following describe physical or chemical change:

a:) A He gas inside a balloon tends to leak out after a few hours
b:) Melting of the ice
c:) burning a piece of paper
d:) Addition of Vinegar (acid) on sodium carbonate

Which of the following properties are Intensive and which are extensive:

a:) length
b:) Volume
c:) Temperature
d:) mass
Measurements
# International System of Units (SI)

## Table 1.2: SI Base Units

<table>
<thead>
<tr>
<th>Base Quantity</th>
<th>Name of Unit</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter</td>
<td>m</td>
</tr>
<tr>
<td>Mass</td>
<td>kilogram</td>
<td>kg</td>
</tr>
<tr>
<td>Time</td>
<td>second</td>
<td>s</td>
</tr>
<tr>
<td>Electrical current</td>
<td>ampere</td>
<td>A</td>
</tr>
<tr>
<td>Temperature</td>
<td>kelvin</td>
<td>K</td>
</tr>
<tr>
<td>Amount of substance</td>
<td>mole</td>
<td>mol</td>
</tr>
<tr>
<td>Luminous intensity</td>
<td>candela</td>
<td>cd</td>
</tr>
</tbody>
</table>
Matter - anything that occupies space and has **mass**.

**mass** – measure of the quantity of matter

SI unit of mass is the **kilogram** (kg)

$1 \text{ kg} = 1000 \text{ g} = 1 \times 10^3 \text{ g}$

**weight** – force that gravity exerts on an object

weight = $c \times$ mass

A 1 kg bar will weigh

on earth, $c = 1.0$

on moon, $c \approx 0.1$

1 kg on earth

0.1 kg on moon
### TABLE 1.3 Prefixes Used with SI Units

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>tera-</td>
<td>T</td>
<td>$1,000,000,000,000$, or $10^{12}$</td>
<td>1 terameter ($Tm$) = $1 \times 10^{12}$ m</td>
</tr>
<tr>
<td>giga-</td>
<td>G</td>
<td>$1,000,000,000$, or $10^9$</td>
<td>1 gigameter ($Gm$) = $1 \times 10^9$ m</td>
</tr>
<tr>
<td>mega-</td>
<td>M</td>
<td>$1,000,000$, or $10^6$</td>
<td>1 megameter ($Mm$) = $1 \times 10^6$ m</td>
</tr>
<tr>
<td>kilo-</td>
<td>k</td>
<td>$1,000$, or $10^3$</td>
<td>1 kilometer ($km$) = $1 \times 10^3$ m</td>
</tr>
<tr>
<td>deci-</td>
<td>d</td>
<td>$1/10$, or $10^{-1}$</td>
<td>1 decimeter ($dm$) = 0.1 m</td>
</tr>
<tr>
<td>centi-</td>
<td>c</td>
<td>$1/100$, or $10^{-2}$</td>
<td>1 centimeter ($cm$) = 0.01 m</td>
</tr>
<tr>
<td>milli-</td>
<td>m</td>
<td>$1/1,000$, or $10^{-3}$</td>
<td>1 millimeter ($mm$) = 0.001 m</td>
</tr>
<tr>
<td>micro-</td>
<td>$\mu$</td>
<td>$1/1,000,000$, or $10^{-6}$</td>
<td>1 micrometer ($\mu$m) = $1 \times 10^{-6}$ m</td>
</tr>
<tr>
<td>nano-</td>
<td>n</td>
<td>$1/1,000,000,000$, or $10^{-9}$</td>
<td>1 nanometer ($nm$) = $1 \times 10^{-9}$ m</td>
</tr>
<tr>
<td>pico-</td>
<td>p</td>
<td>$1/1,000,000,000,000$, or $10^{-12}$</td>
<td>1 picometer ($pm$) = $1 \times 10^{-12}$ m</td>
</tr>
</tbody>
</table>
**Volume** – SI derived unit for volume is cubic meter \((m^3)\)

- \(1\text{ cm}^3 = (1 \times 10^{-2}\text{ m})^3 = 1 \times 10^{-6}\text{ m}^3\)
- \(1\text{ dm}^3 = (1 \times 10^{-1}\text{ m})^3 = 1 \times 10^{-3}\text{ m}^3\)
- \(1\text{ L} = 1000\text{ mL} = 1000\text{ cm}^3 = 1\text{ dm}^3\)

\[
1\text{ mL} = 1\text{ cm}^3
\]
Density – SI derived unit for density is kg/m³

\[ 1 \text{ g/cm}^3 = 1 \text{ g/mL} = 1000 \text{ kg/m}^3 \]

density = \frac{\text{mass}}{\text{volume}} \quad \quad d = \frac{m}{V}

A piece of platinum metal with a density of 21.5 g/cm³ has a volume of 4.49 cm³. What is its mass?

\[ d = \frac{m}{V} \]

\[ m = d \times V = 21.5 \text{ g/cm}^3 \times 4.49 \text{ cm}^3 = 96.5 \text{ g} \]
\[ K = ^0C + 273.15 \]

- \( 273 \text{ K} = 0 ^\circ \text{C} \)
- \( 373 \text{ K} = 100 ^\circ \text{C} \)

\[ ^0F = \frac{9}{5} \times ^0C + 32 \]

- \( 32 ^\circ \text{F} = 0 ^\circ \text{C} \)
- \( 212 ^\circ \text{F} = 100 ^\circ \text{C} \)
Convert 172.9 °F to degrees Celsius.

\[ ^\circ F = \frac{9}{5} x ^\circ C + 32 \]

\[ ^\circ F - 32 = \frac{9}{5} x ^\circ C \]

\[ \frac{5}{9} \times (^\circ F - 32) = ^\circ C \]

\[ ^\circ C = \frac{5}{9} \times (172.9 - 32) = 78.3 \]
Scientific Notation

The number of atoms in 12 g of carbon:

602,200,000,000,000,000,000,000

6.022 x 10^{23}

The mass of a single carbon atom in grams:

0.000000000000000000000000199

1.99 x 10^{-23}

\[ N \times 10^n \]

N is a number between 1 and 10

n is a positive or negative integer
Scientific Notation

568.762

\[ n > 0 \]

\[ 568.762 = 5.68762 \times 10^2 \]

move decimal left

0.00000772

\[ n < 0 \]

\[ 0.00000772 = 7.72 \times 10^{-6} \]

move decimal right

Addition or Subtraction

1. Write each quantity with the same exponent \( n \)
2. Combine \( N_1 \) and \( N_2 \)
3. The exponent, \( n \), remains the same

\[ 4.31 \times 10^4 + 3.9 \times 10^3 = \]

\[ 4.31 \times 10^4 + 0.39 \times 10^4 = \]

\[ 4.70 \times 10^4 \]
Scientific Notation

**Multiplication**
1. Multiply $N_1$ and $N_2$
2. Add exponents $n_1$ and $n_2$

$$(4.0 \times 10^{-5}) \times (7.0 \times 10^3) =$$
$$(4.0 \times 7.0) \times (10^{-5+3}) =$$
$$28 \times 10^{-2} =$$
$$2.8 \times 10^{-1}$$

**Division**
1. Divide $N_1$ and $N_2$
2. Subtract exponents $n_1$ and $n_2$

$$8.5 \times 10^4 \div 5.0 \times 10^9 =$$
$$(8.5 \div 5.0) \times 10^{4-9} =$$
$$1.7 \times 10^{-5}$$
Significant Figures

• Any digit that is not zero is significant
  1.234 kg  4 significant figures

• Zeros between nonzero digits are significant
  606 m   3 significant figures

• Zeros to the left of the first nonzero digit are not significant
  0.08 L   1 significant figure

• If a number is greater than 1, then all zeros to the right of the decimal point are significant
  2.0 mg  2 significant figures

• If a number is less than 1, then only the zeros that are at the end and in the middle of the number are significant
  0.00420 g  3 significant figures
How many significant figures are in each of the following measurements?

24 mL 2 significant figures
3001 g 4 significant figures
0.0320 m³ 3 significant figures
6.4 x 10⁴ molecules 2 significant figures
560 kg 2 significant figures
Significant Figures

Addition or Subtraction

The answer cannot have more digits to the right of the decimal point than any of the original numbers.

\[
\begin{align*}
89.332 & + 1.1 & \quad \text{one significant figure after decimal point} \\
\hline 
90.432 & \quad \text{round off to 90.4} \\
\end{align*}
\]

\[
\begin{align*}
3.70 & - 2.9133 & \quad \text{two significant figures after decimal point} \\
\hline 
0.7867 & \quad \text{round off to 0.79}
\end{align*}
\]
Significant Figures

**Multiplication or Division**

The number of significant figures in the result is set by the original number that has the *smallest* number of significant figures.

\[
4.51 \times 3.6666 = 16.536366 = 16.5
\]

3 sig figs

round to

3 sig figs

\[
6.8 \div 112.04 = 0.0606926 = 0.061
\]

2 sig figs

round to

2 sig figs
Significant Figures

**Exact Numbers**

Numbers from definitions or numbers of objects are considered to have an infinite number of significant figures.

The average of three measured lengths; 6.64, 6.68 and 6.70?

\[
\frac{6.64 + 6.68 + 6.70}{3} = \frac{20.02}{3} = 6.67333 = 6.67 \approx 7
\]

Because 3 is an *exact number*
**Accuracy** – how close a measurement is to the *true* value

**Precision** – how close a set of measurements are to each other

- accurate & precise
- precise but *not* accurate
- *not* accurate & *not* precise