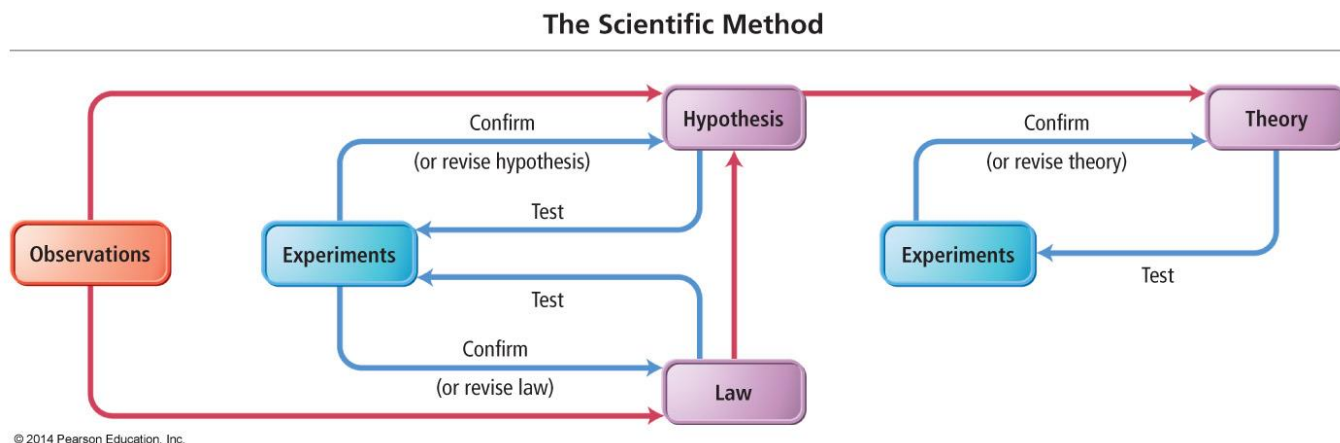


## THE SCIENTIFIC METHOD

- The scientific method is a **process** of creative thinking and testing aimed at **objective** and **verifiable** discoveries. It is generally composed of the following steps:



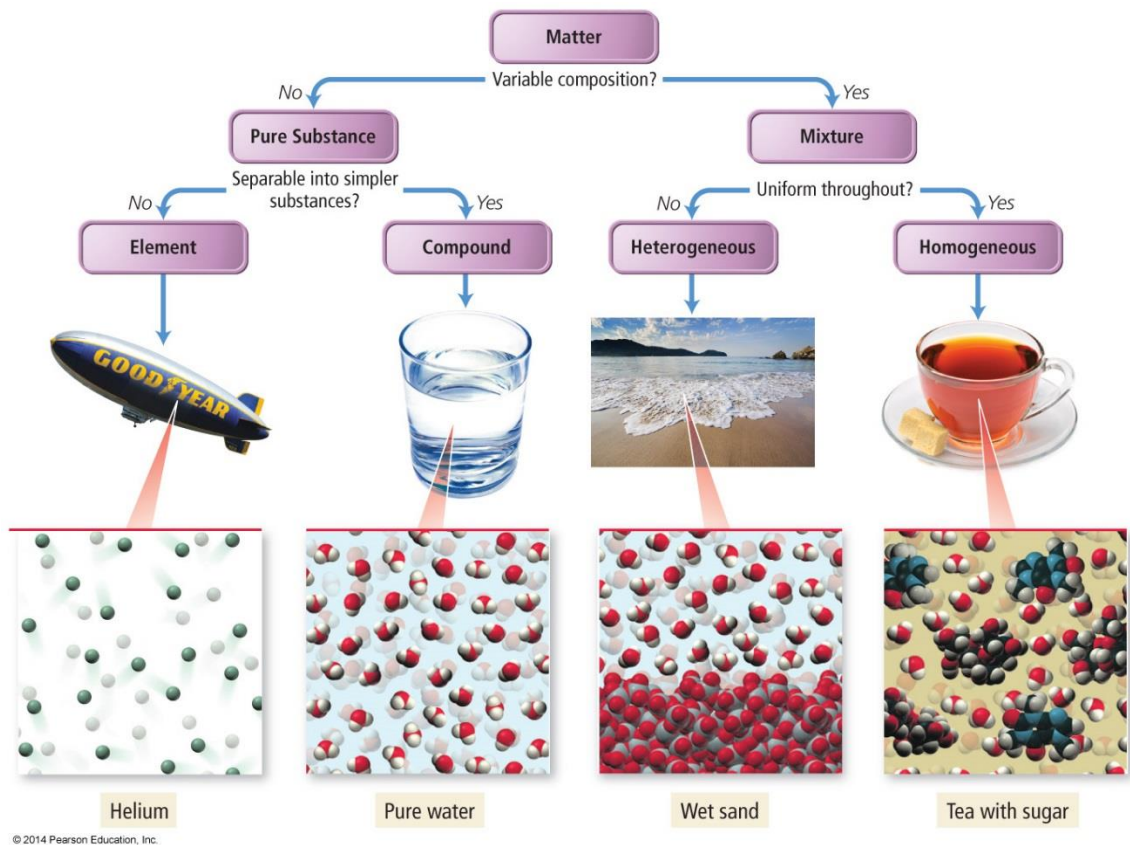
### Examples:

- Classify each statement below as *an observation, a law, or a theory*:

- Chlorine is a highly reactive gas. \_\_\_\_\_
- If elements are listed in order of increasing mass of their atoms, their chemical reactivity follows a repeating pattern. \_\_\_\_\_
- Neon is an inert gas. \_\_\_\_\_
- The reactivity of elements depends on the arrangement of their electrons. \_\_\_\_\_

## CLASSIFICATION OF MATTER

- Matter can be classified according to its composition, as shown below:



### Examples:

- Classify each substance below as element, compound, homogeneous mixture or heterogeneous mixture:

a) wine \_\_\_\_\_

b) iron \_\_\_\_\_

c) beef stew \_\_\_\_\_

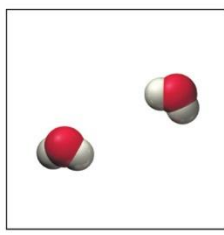
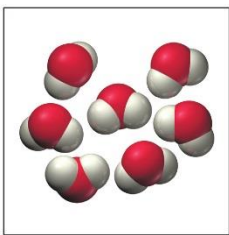
d) carbon monoxide \_\_\_\_\_

**PHYSICAL & CHEMICAL CHANGES AND PROPERTIES**

- Changes that alter only state or appearance of matter, but not its composition, are **physical changes**. In contrast, changes that alter the composition of matter are **chemical changes**.
- A **physical property** is a property that a substance displays without changing its composition, whereas a **chemical property** is a property that a substance displays only by changing its composition via a chemical change.

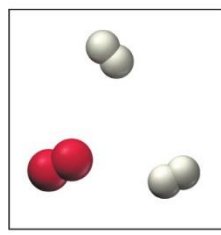
**Examples:**

- Classify each property as physical or chemical:
  - the boiling point of alcohol \_\_\_\_\_
  - the tendency of iron to rust \_\_\_\_\_
  - the temperature at which dry ice sublimates \_\_\_\_\_
- Classify each change as physical or chemical:
  - Sugar burns when heated in a skillet \_\_\_\_\_
  - Salt dissolves in water \_\_\_\_\_
  - A platinum ring becomes dull because of continued abrasion \_\_\_\_\_
  - A silver fork becomes tarnished after sitting in air \_\_\_\_\_
- The diagram on the left represents liquid water molecules in a pan. Which of the 3 diagrams (a, b, or c) best represents these molecules after they have been vaporized?

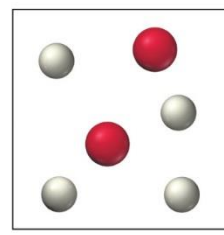


(a)

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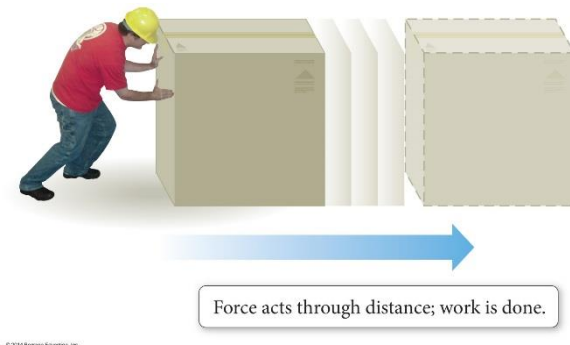
(b)



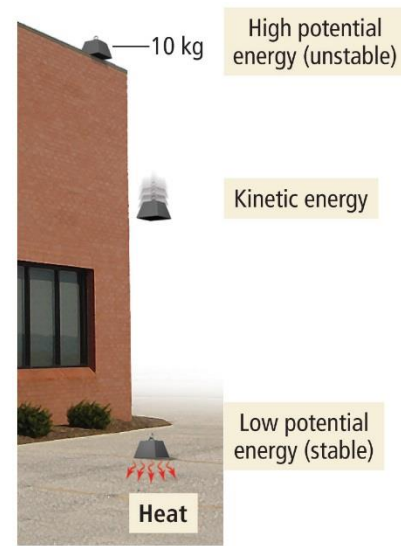
(c)

## ENERGY AND PHYSICAL & CHEMICAL CHANGES

- **Energy** is the capacity to do work. **Work** is defined as the action of a force through a distance.

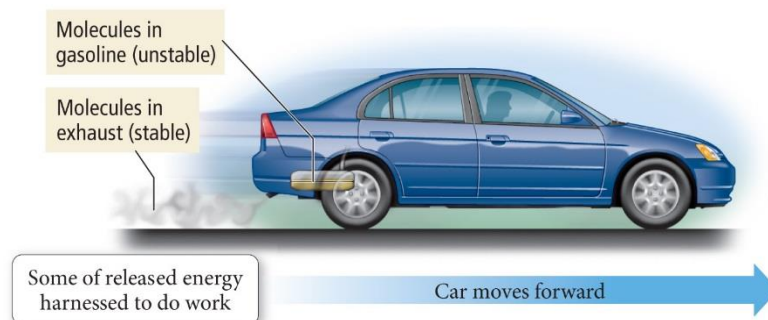


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- The total energy of an object is the sum of its **kinetic** (moving) energy and its **potential** (stored) energy.
- Energy can be converted from one form to another during a physical or chemical change. However, energy is neither created nor destroyed.
- Therefore energy is always conserved during a physical or chemical change. This principle is known as the **law of conservation of energy**.
- Objects or systems with high potential energy tend to be unstable, while those with lower potential energy tend to be stable. Systems with high potential energy tend to change in a direction that lowers their potential energy, releasing energy into the surroundings.



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**UNITS OF MEASUREMENT**

- The standard units of measurement in the SI system are listed below:

**TABLE 1.1 SI Base Units**

Quantity	Unit	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A
Luminous intensity	Candela	cd

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- The prefix multipliers used with the SI standard units are shown below:

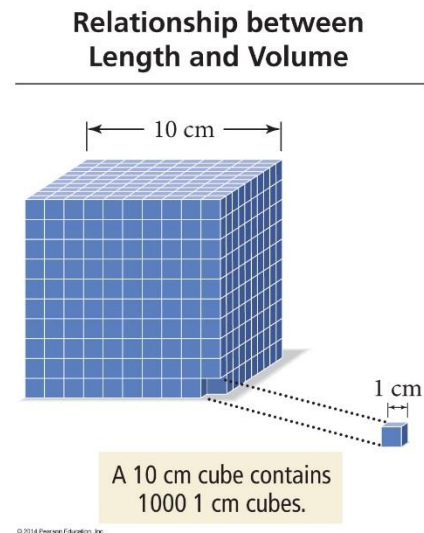
**TABLE 1.2 SI Prefix Multipliers**

Prefix	Symbol	Multiplier
exa	E	1,000,000,000,000,000,000 (10 <sup>18</sup> )
peta	P	1,000,000,000,000,000 (10 <sup>15</sup> )
tera	T	1,000,000,000,000 (10 <sup>12</sup> )
giga	G	1,000,000,000 (10 <sup>9</sup> )
mega	M	1,000,000 (10 <sup>6</sup> )
kilo	k	1000 (10 <sup>3</sup> )
deci	d	0.1 (10 <sup>-1</sup> )
centi	c	0.01 (10 <sup>-2</sup> )
milli	m	0.001 (10 <sup>-3</sup> )
micro	μ	0.000001 (10 <sup>-6</sup> )
nano	n	0.000000001 (10 <sup>-9</sup> )
pico	p	0.000000000001 (10 <sup>-12</sup> )
femto	f	0.000000000000001 (10 <sup>-15</sup> )
atto	a	0.000000000000000001 (10 <sup>-18</sup> )

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## VOLUME & DENSITY

- In addition to the standard SI units mentioned previously, two important derived units are also used in chemistry. These are volume and density.
- Volume is the amount of space an object occupies, and is related to its linear dimensions. Therefore, any unit of length, when cubed, becomes a unit of volume. Some examples are  $\text{cm}^3$ ,  $\text{m}^3$ ,  $\text{ft}^3$  and  $\text{in}^3$ . The relationship between length and volume is shown on the right.
- Density is the ratio of mass to volume of a substance. Density is a characteristic property of matter that depends on temperature.
- Density is an *intensive* property of matter, while mass and volume are examples of *extensive* properties of matter.



### Examples:

1. The density of copper decreases as temperature increases. Which statement below accurately describes the change in a sample of copper when it is warmed from room temperature to  $95^\circ\text{C}$ ?
  - a) The sample will become lighter.
  - b) The sample will become heavier.
  - c) The sample will expand.
  - d) The sample will contract.
2. How many mL of olive oil ( $d = 0.92 \text{ g/mL}$ ) weigh the same as 1.2 L of gasoline ( $d = 0.66 \text{ g/mL}$ ).

**SIGNIFICANT FIGURES & CALCULATIONS**

- When measured quantities are used in calculations, the result of the calculations must reflect the precision of the measured quantity. Precision should not be gained or lost during a mathematical operation.
- In **multiplication or division**, the result carries the same number of **significant figures** as the quantity with the fewest significant figures. In **addition or subtraction**, the result carries the same number of **decimals** as the quantity with the fewest decimal places.
- To avoid rounding errors in multistep calculations, round only the final step-do not round intermediate steps. If intermediate answers are written down for later use, keep track of significant figures by underlining the least significant digit.
- In mixed operations (those involving both multiplication or division and addition or subtraction), perform each operation, and round accordingly after each.

**Examples:**

1. Perform each calculation with the correct number of significant figures:

a)  $\frac{85.3 - 21.489}{5.342} =$

b)  $\frac{1.7 \times 10^6}{2.63 \times 10^5} + 7.33 =$

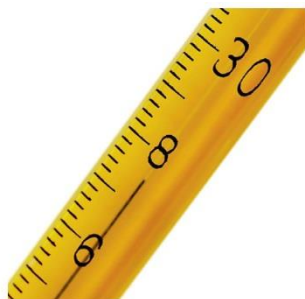
c)  $(9443 + 45 - 9.9) \times (8.1 \times 10^6) =$

d)  $\frac{(2.80 \times 10^4)(1.4 \times 10^{-3})^2}{7.12 \times 10^8} =$

2. Read each measurement below to the correct number of significant figures:



(a)



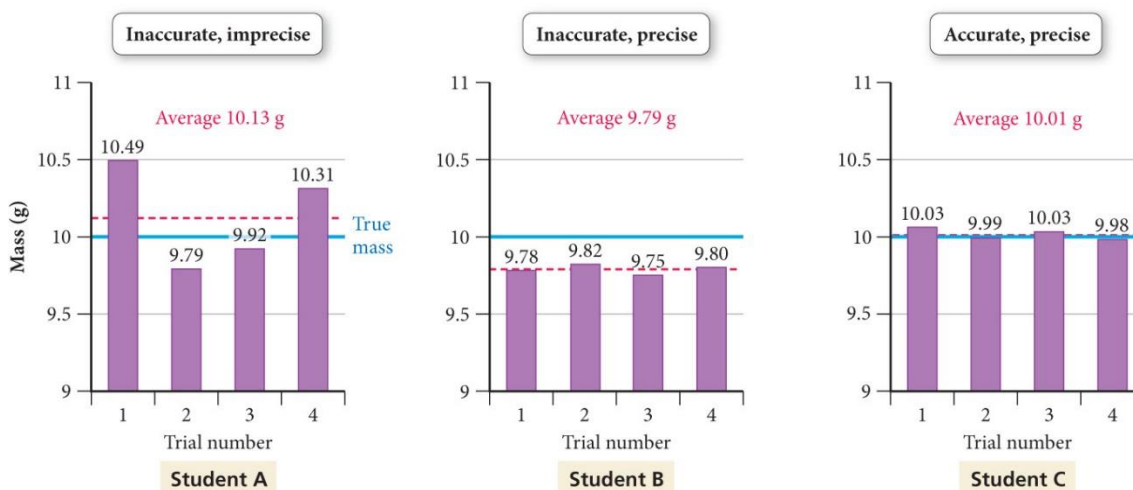
(b)



(c)

**ACCURACY & PRECISION**

- Accuracy refers to how close the measured value is to the actual value. Precision refers to how close a series of measurements are to one another, or how reproducible they are.
- Random errors are those that have equal probability of being too high or too low. Almost all measurements have some degree of random error. Random errors can be averaged out by performing multiple trials.
- Systematic errors are those that tend towards being either too high or too low. Systematic errors do not average out by performing multiple trials.



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**Answers to In-Chapter Problems:**

<i>Page</i>	<i>Example No.</i>	<i>Answer</i>
1	1	a) Observation b) law c) observation d) theory
2	1	a) homogeneous mixture c) heterogeneous mixture b) element d) compound
3	1	a) physical b) chemical c) physical
	2	a) chemical b) physical c) physical d) chemical
	3	a
6	1	c
	2	860 mL
7	1	a) 11.9 b) 13.8 c) $7.7 \times 10^{10}$ d) $7.7 \times 10^{-11}$
	2	a) 4.48 mL b) 27.43 °C c) 0.873 g
9	1	7.3 hrs
	2	$1.33 \times 10^5$ kg
10	3	84 m
	4	$1.99 \times 10^5$ kg
	5	$3.0 \times 10^3$ lb