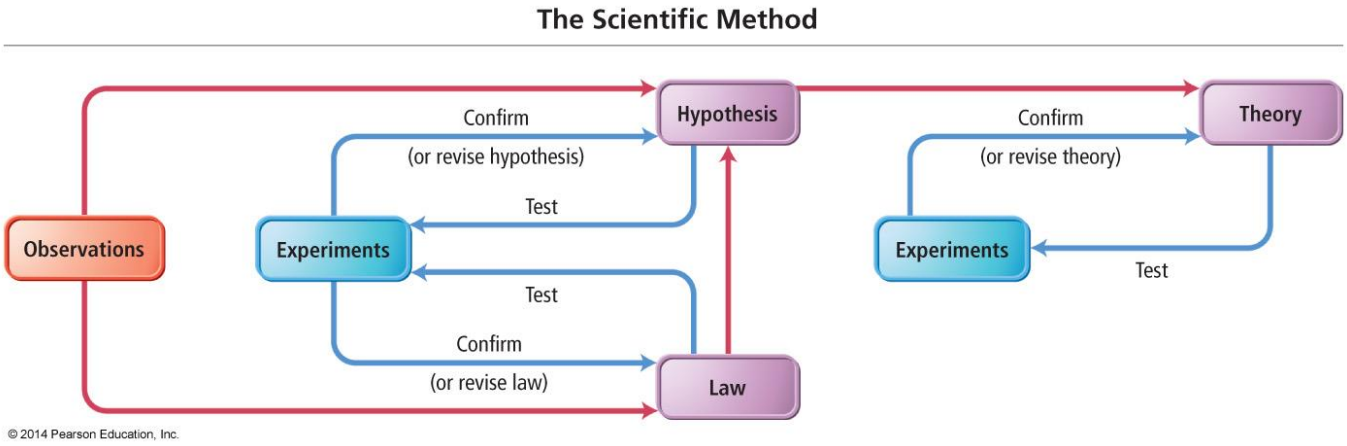
THE SCIENTIFIC METHOD

- 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:

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

   a) Chlorine is a highly reactive gas. _____

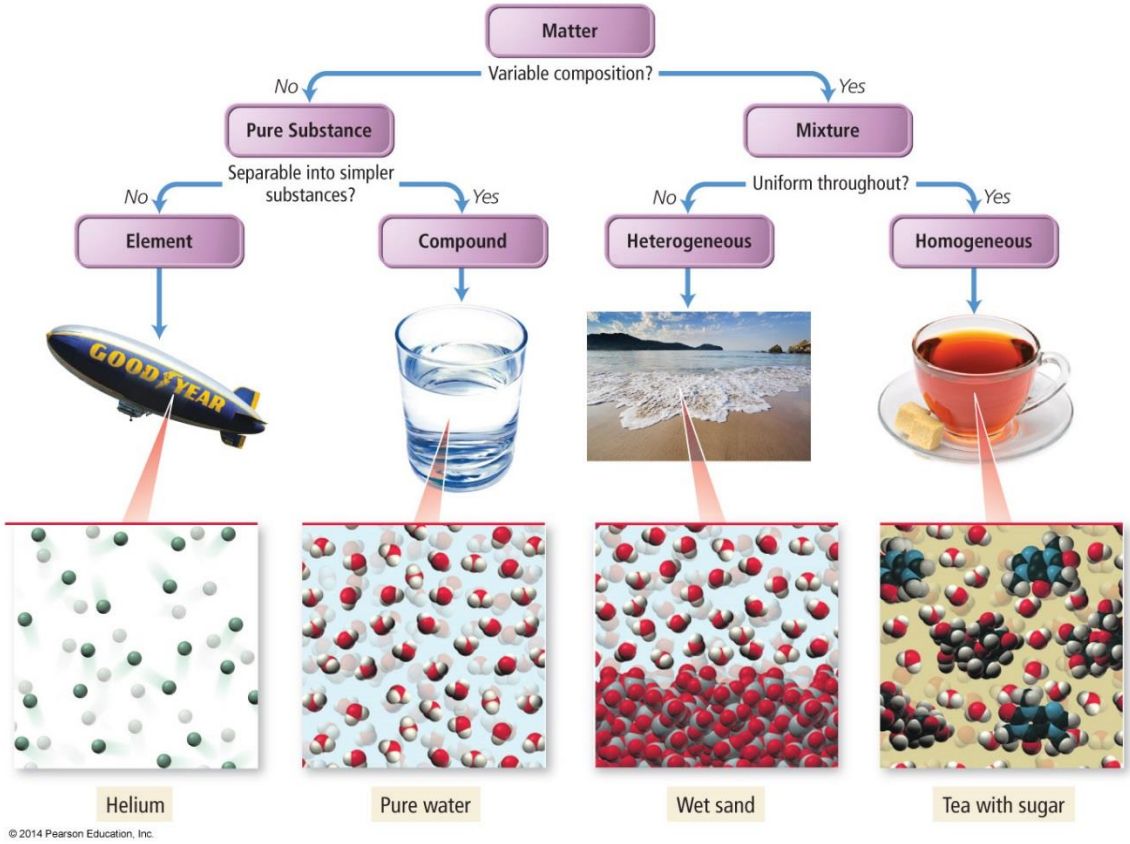
   b) If elements are listed in order of increasing mass of their atoms, their chemical reactivity follows a repeating pattern. _____

   c) Neon is an inert gas. _____

   d) 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:

1. 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:

1. Classify each property as physical or chemical:

   a) the boiling point of alcohol _____

   b) the tendency of iron to rust _____

   c) the temperature at which dry ice sublimes _____

2. Classify each change as physical or chemical:

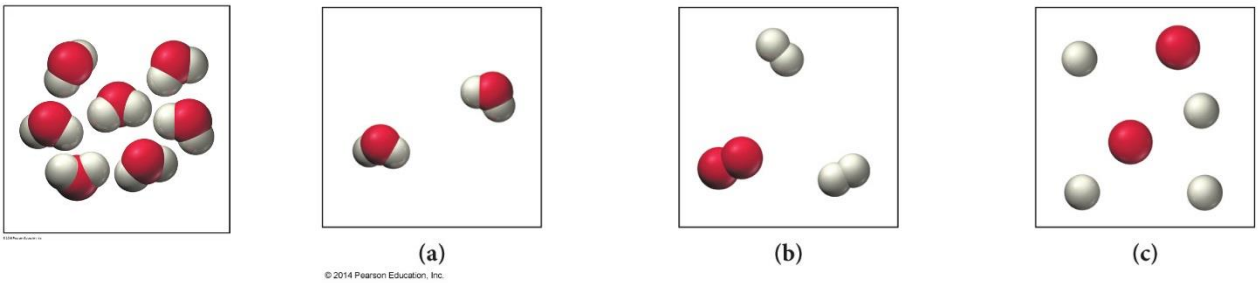
   a) Sugar burns when heated in a skillet _____

   b) Salt dissolves in water_____

   c) A platinum ring becomes dull because of continued abrasion _____

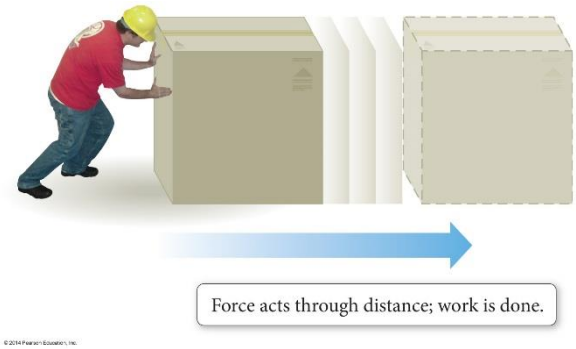
   d) A silver fork becomes tarnished after sitting in air _____

3. 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?



ENERGY AND PHYSICAL & CHEMICAL CHANGES

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

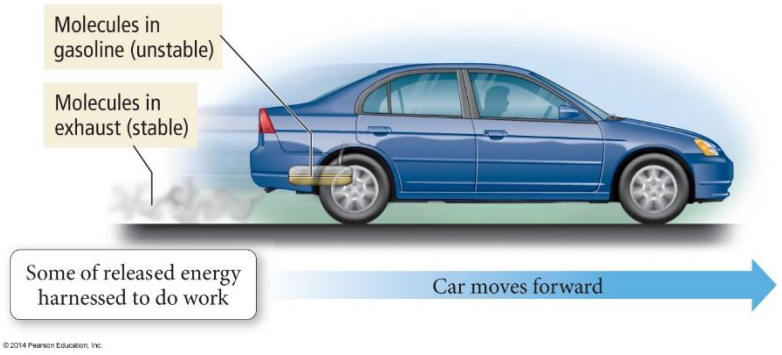


- The total energy of an object is the sum of its ***kinetic*** (moving) energy and its ***potential*** (stored) energy.

- 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.



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

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

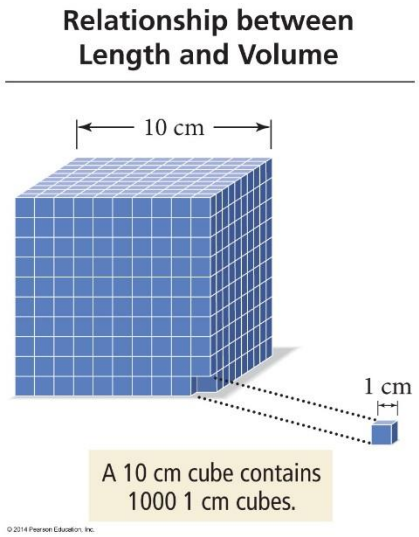
VOLUME & DENSITY

- 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 dimen-sions.Therefore, any unit of length, when cubed , becomes a unit of volume. Some examples are cm^3, m^3, ft^3 and 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°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 g/mL) weigh the same as 1.2 L of gasoline (d = 0.66 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) $\dfrac{85.3 - 21.489}{5.342} =$

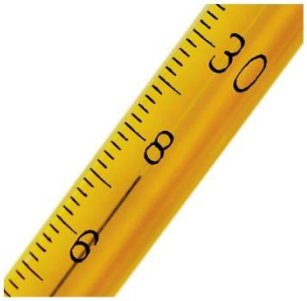
b) $\dfrac{1.7\text{x}10^{6}}{2.63\text{x}10^{5}} + 7.33 =$

c) $(9443 + 45 - 9.9) \text{ x } (8.1\text{x}10^{6}) =$

d) $\dfrac{(2.80\text{x}10^{4})(1.4\text{x}10^{-3})^{2}}{7.12\text{x}10^{8}} =$

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

(a)



(b)

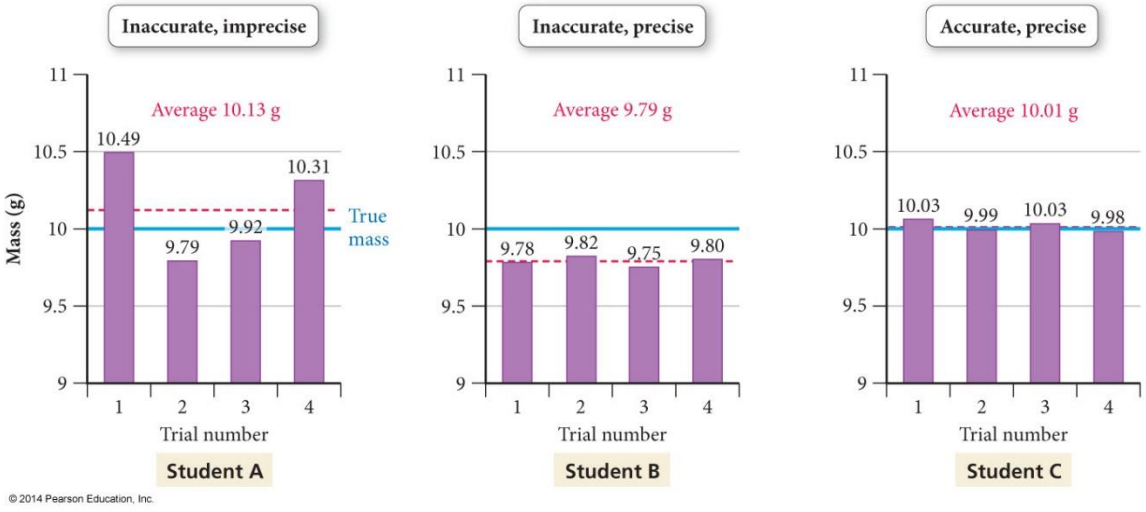
(c)

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 have tend towards being either too high or too low. Systematic errors do not average out by performing multiple trials.



UNIT CONVERSIONS & PROBLEM-SOLVING STRATEGIES

- Many chemistry problems involve unit conversions and use of various specific equations. Learning and mastering various strategies will help solve both of these type of problems.

- Using units as a guide to solving problems is called ***dimensional analysis***. Units should always be used in calculations; they are multiplied, divided and cancelled as any other algebraic quantity. This method of problem solving uses commonly available ***conversion factors.***

- Many other problems that involve other topics are solved using the following general strategy:

  - Identify starting point (given information)
  - Identify end point (what you are asked to find)
  - Devise a conceptual plan to get from start to end.

Given ⇒ Conceptual plan ⇒ Find

Examples:

1. A cyclist rides at an average speed of 18 mi/hr. If she want to bike 212 km, how many hours must she ride? (1 km = 0.6214 mi)

2. The mass of fuel in a jet must be calculated before each flight to ensure that the jet is not too heavy to fly. A 747 is fueled with 173,231 L of jet fuel. If the density of the fuel is 0.768 g/cm^3, what is the mass of the fuel in kg?

3. Rolls of aluminum are 304 mm wide and 0.016 mm thick. What maximum length of aluminum foil (in m) can be made from 1.10 kg of aluminum? (density of Al = 2.70 g/cm^3)

4. An iceberg has a volume of 7655 cubic feet. What is the mass of the ice (in kg) composing the iceberg at 0°C? (density of ice at 0°C = 0.917 g/cm^3)

5. Two minerals of iron are geothite, FeO(OH) (62.9% Fe) and magnetite, Fe_3O_4 (72.4% Fe). An iron ore sample contains 55% magnetite and 45% goethite. What mass of iron (in lbs) can be extracted from 2.0 metric tons or this iron ore? (1 ton = 1000 kg)

Answers to In-Chapter Problems:

Page	***Example No.***	***Answer***
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) 7.7×10^{10} d) 7.7×10^{-11}
	2	a) 4.48 mL b) 27.43 °C c) 0.873 g
9	1	7.3 hrs
	2	1.33×10^{5} kg
10	3	84 m
	4	1.99×10^{5} kg
	5	3.0×10^{3} lb