CHEM 103
CHEMISTRY I

Chapter 1
INTRODUCTION:
MATTER AND MEASUREMENT

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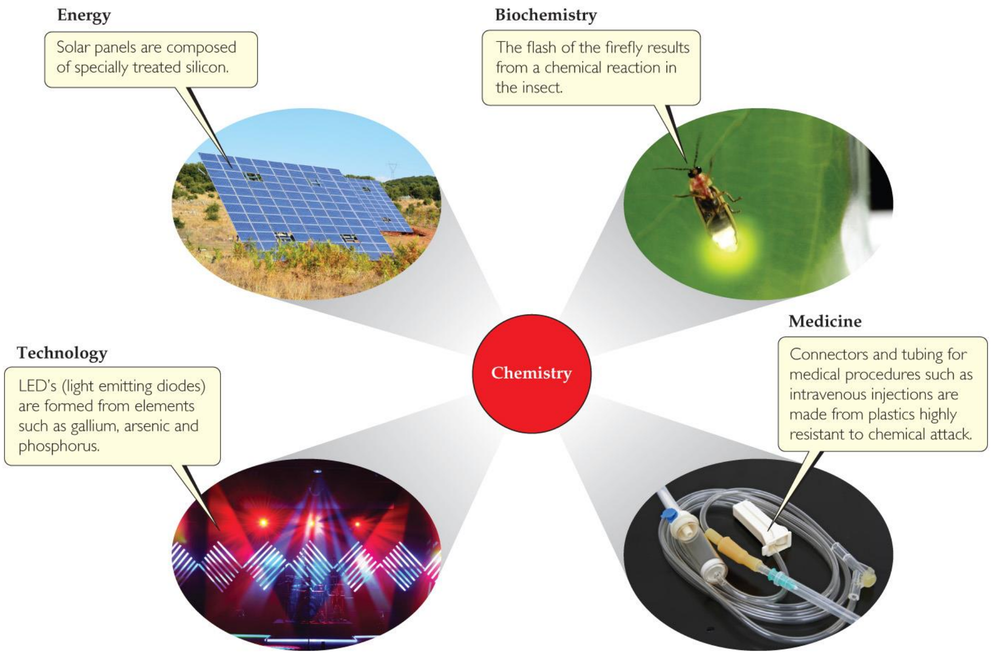
Chemistry



- Chemistry is the study of the **properties** and **behavior** of **matter**.
- It is central to our fundamental understanding of many science-related fields.

Matter

Matter is anything that has mass and takes up (occupies) space. **Property** is any characteristic that allows us to recognize a particular type of matter and to distinguish it from other types.

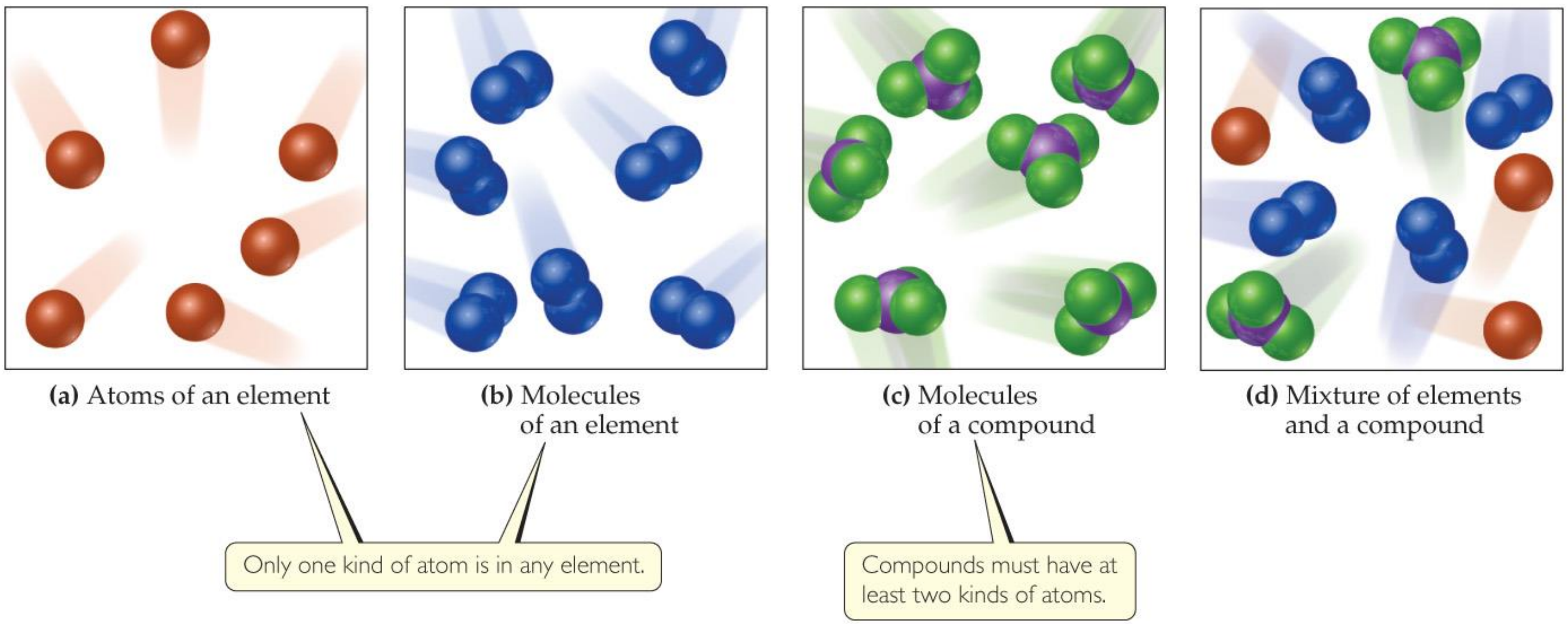
Tremendous variety of matter in our world is due to combinations of only about 100 substances called elements.

A chemical element is a substance made up of only a single type of atom.

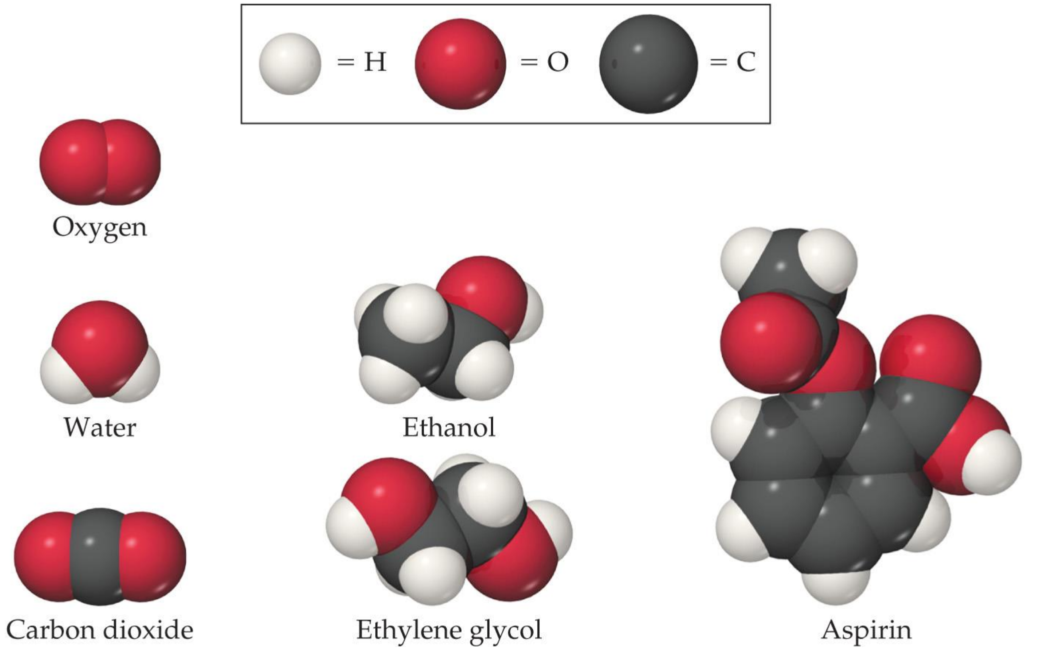
Atoms are the building blocks of matter.

In molecules, two or more atoms are joined together in specific shapes.

A compound is made of two or more different kinds of elements.



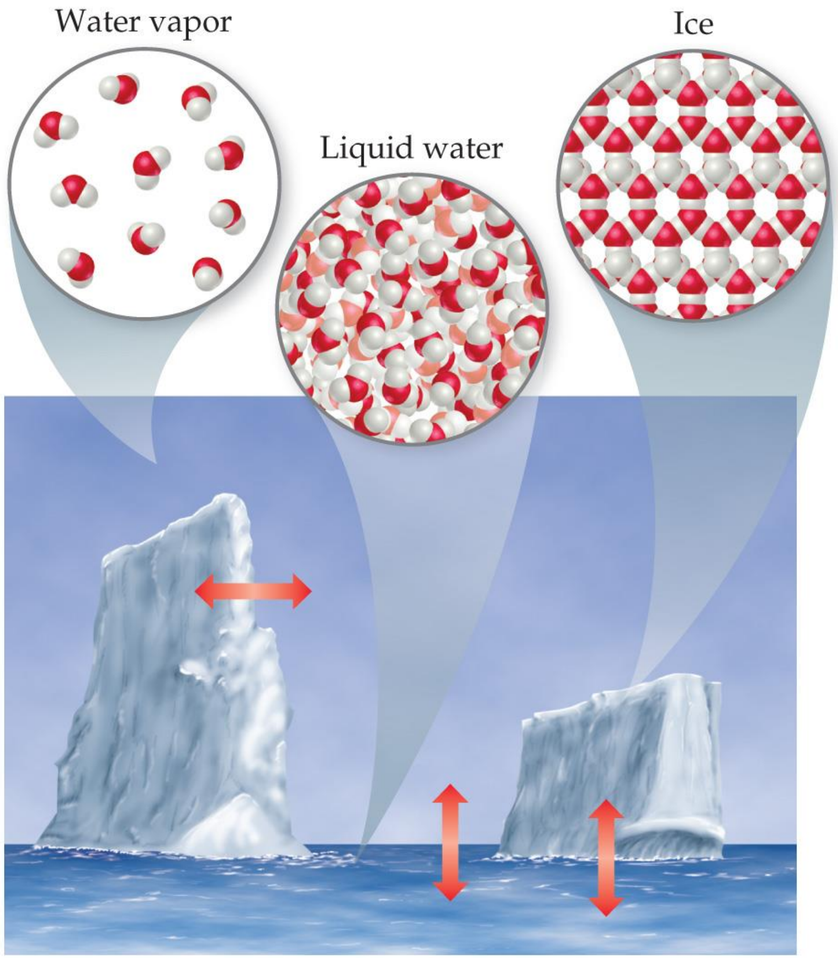
Matter



Note: Balls of different colors are used to represent atoms of different elements. Attached balls represent connections between atoms that are seen in nature. These groups of atoms are called **molecules**.

Classifications of Matter

Matter can be classified by two fundamental ways according to its physical state (gas, liquid or solid) or its composition (element, compound or mixture).



- A sample of matter can be a gas, a liquid , or a solid.

Classification of Matter Based on Composition

Most forms of matter are not chemically pure. However, we can seperate these forms of matter into pure substances.

A pure substance is matter that has distinct properties and a composition that does not vary from sample to sample.

All substances are either elements or compounds.

Elements are substances that cannot be decomposed into simpler substances. Each element is composed of only one kind of atom.

Table 1.2 Some Common Elements and Their Symbols

Carbon	C	Aluminum	Al	Copper	Cu (from *cuprum*)
Fluorine	F	Bromine	Br	Iron	Fe (from *ferrum*)
Hydrogen	H	Calcium	Ca	Lead	Pb (from *plumbum*)
Iodine	I	Chlorine	Cl	Mercury	Hg (from *hydrargyrum*)
Nitrogen	N	Helium	He	Potassium	K (from *kalium*)
Oxygen	O	Lithium	Li	Silver	Ag (from *argentum*)
Phosphorus	P	Magnesium	Mg	Sodium	Na (from *natrium*)
Sulfur	S	Silicon	Si	Tin	Sn (from *stannum*)

Classification of Matter Based on Composition

Most elements can interact with other elements to form compounds.

Compounds are substances composed of two or more elements; they contain two or more kinds of atoms.

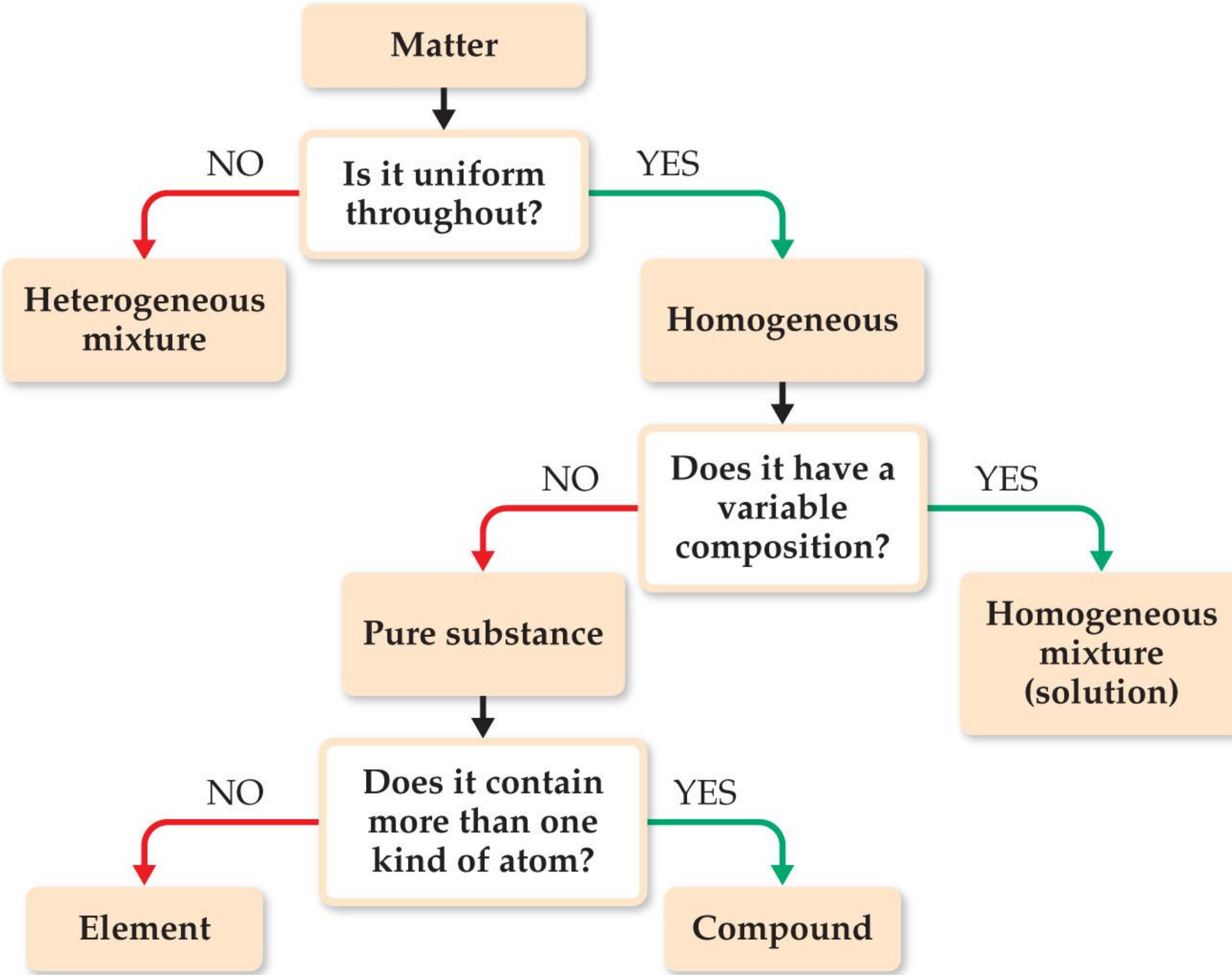
The observation that the elemental composition of a compound is always the same is known as the law of constant composition (or the law of definite proportions).

Most of the matter consists of mixtures of different substances.

Mixtures are combinations of two or more substances in which each substance retains its chemical identity.
The substances making up a mixture are called components of mixture.

Some mixtures do not have the same composition, properties, and appearance throughout. Such mixtures are heterogeneous.
Mixtures that are uniform throughout are homogeneous. Homogeneous mixtures are also called solutions.

Classification of Matter Based on Composition



Properties of Matter

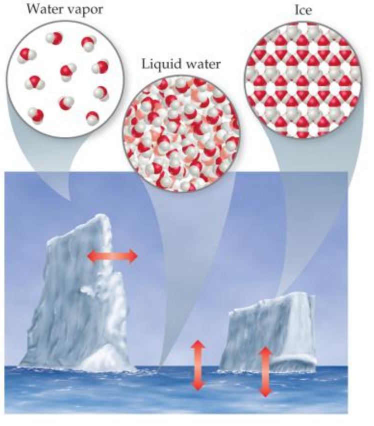
- **Physical Properties** can be observed without changing a substance into another substance.
  - Some examples include boiling point, density, mass, or volume.
- **Chemical Properties** can only be observed when a substance is changed into another substance.
  - Some examples include flammability, corrosiveness, or reactivity with acid.

- **Intensive Properties** are independent of the amount of the substance that is present.
  - Examples include density, boiling point, or color.

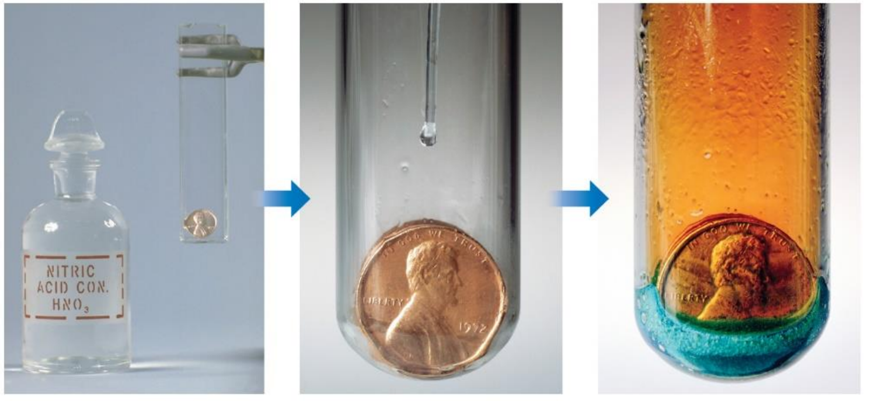
- **Extensive Properties** depend upon the amount of the substance present.
  - Examples include mass, volume, or energy.

Physical and Chemical Changes

- **Physical Changes** are changes in matter that do *not* change the composition of a substance.
  - Examples include changes of state, temperature, and volume.



- **Chemical Changes** result in new substances.
  - Examples include combustion, oxidation, and decomposition.



Seperation of Mixtures

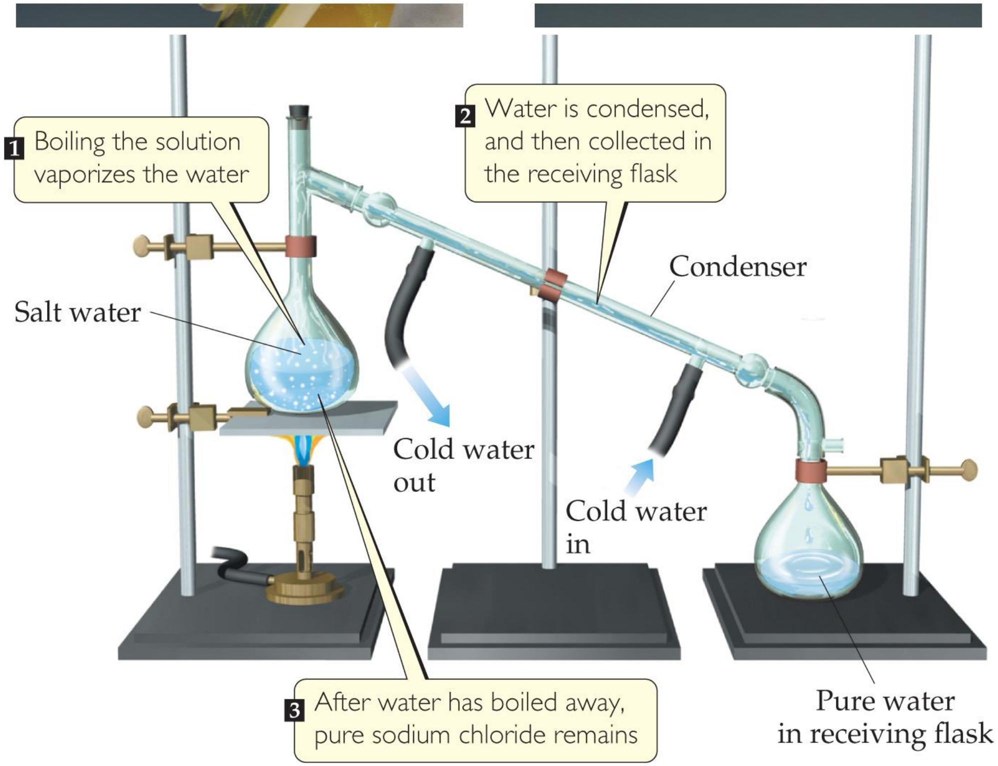
Mixtures can be separated based on physical properties of the components of the mixture. Some methods used are

- filtration.
- distillation.
- chromatography.

Filtration

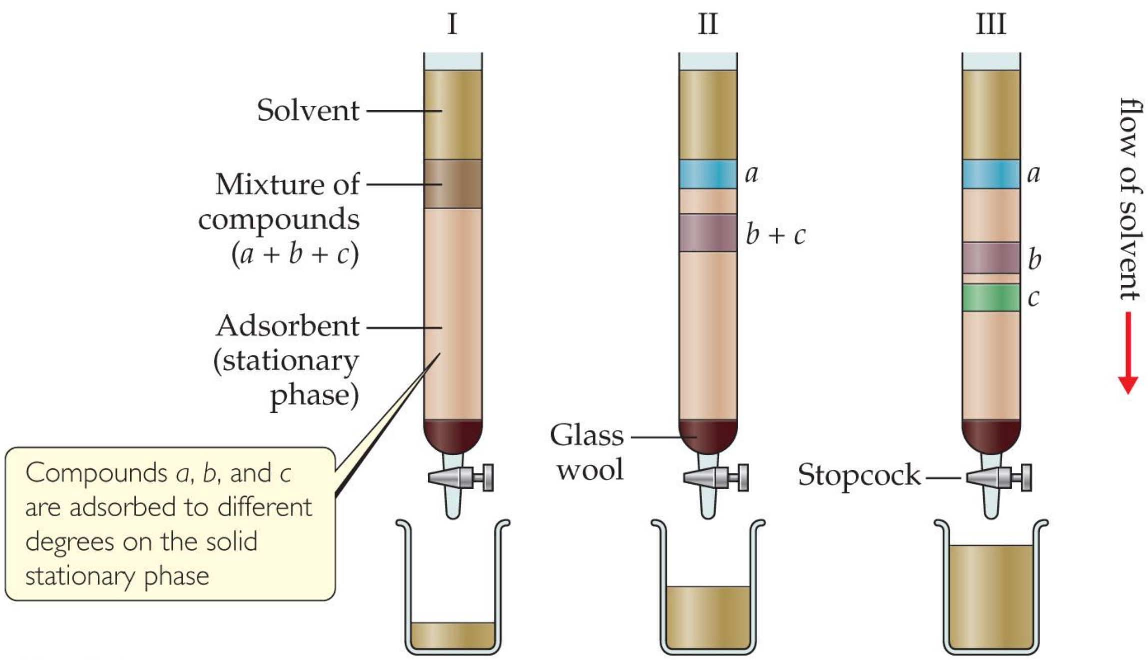
In filtration, solid substances are separated from liquids and solutions.

Distillation



Distillation uses differences in the boiling points of substances to separate a homogeneous mixture into its components.

Chromatography



This technique separates substances on the basis of differences in the ability of substances to adhere to the solid surface, in this case, dyes to paper.

Units of Measurement

Many properties of matter are quantitative so they are associated with numbers.

The units used for scientific measurements are those of the metric system. *The International System of Units* (SI system) has seven base units from which all other units are derived.

Table 1.4 SI Base Units

Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s or sec
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A or amp
Luminous intensity	Candela	cd

Units of Measurement

Prefixes convert the base units into units that are appropriate for common usage or appropriate measure.

Table 1.5 Prefixes Used in the Metric System and with SI Units

Prefix	Abbreviation	Meaning	Example	
Peta	P	10^{15}	1 petawatt (PW)	$= 1 \times 10^{15}$ watts[a]
Tera	T	10^{12}	1 terawatt (TW)	$= 1 \times 10^{12}$ watts
Giga	G	10^{9}	1 gigawatt (GW)	$= 1 \times 10^{9}$ watts
Mega	M	10^{6}	1 megawatt (MW)	$= 1 \times 10^{6}$ watts
Kilo	k	10^{3}	1 kilowatt (kW)	$= 1 \times 10^{3}$ watts
Deci	d	10^{-1}	1 deciwatt (dW)	$= 1 \times 10^{-1}$ watt
Centi	c	10^{-2}	1 centiwatt (cW)	$= 1 \times 10^{-2}$ watt
Milli	m	10^{-3}	1 milliwatt (mW)	$= 1 \times 10^{-3}$ watt
Micro	μ[b]	10^{-6}	1 microwatt (μW)	$= 1 \times 10^{-6}$ watt
Nano	n	10^{-9}	1 nanowatt (nW)	$= 1 \times 10^{-9}$ watt
Pico	p	10^{-12}	1 picowatt (pW)	$= 1 \times 10^{-12}$ watt
Femto	f	10^{-15}	1 femtowatt (fW)	$= 1 \times 10^{-15}$ watt
Atto	a	10^{-18}	1 attowatt (aW)	$= 1 \times 10^{-18}$ watt
Zepto	z	10^{-21}	1 zeptowatt (zW)	$= 1 \times 10^{-21}$ watt

[a]The watt (W) is the SI unit of power, which is the rate at which energy is either generated or consumed. The SI unit of energy is the joule (J); $1\ J = 1\ kg \cdot m^2/s^2$ and $1\ W = 1\ J/s$.

[b]Greek letter mu, pronounced "mew."

SI Units

Mass

Mass is a measure of the amount of material in an object. SI uses the kilogram as the base unit. The metric system uses the gram as the base unit.

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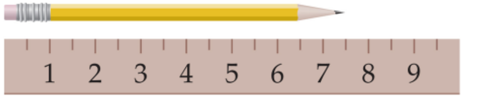
Length

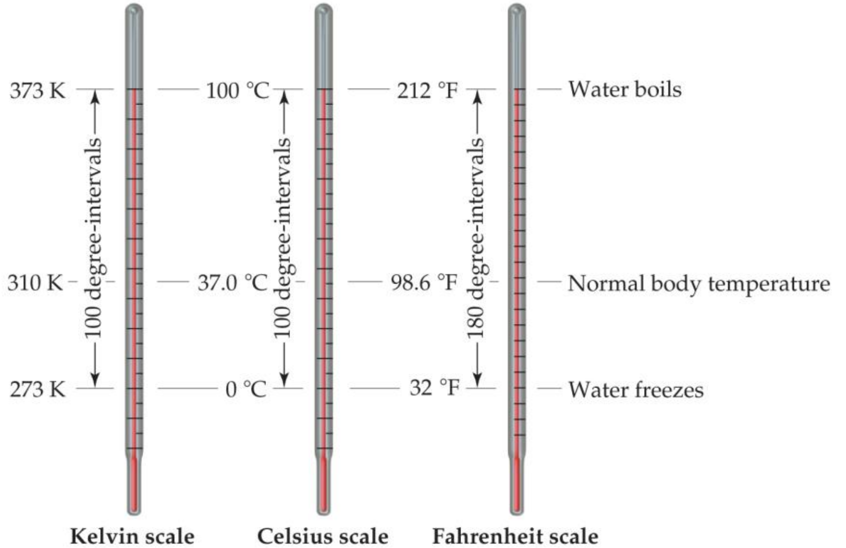
Length is a measure of distance. The meter is the base unit.



SI Units

Temperature

- In general usage, **temperature** is considered the “hotness and coldness” of an object that determines the direction of heat flow.
- Heat flows spontaneously from an object with a higher temperature to an object with a lower temperature.
- In scientific measurements, the Celsius and Kelvin scales are most often used.
- The Celsius scale is based on the properties of water.
  0 °C is the freezing point of water.
  100 °C is the boiling point of water.
- The Kelvin is the SI unit of temperature.



$$K = °C + 273.15$$

$$°F = 9/5(°C) + 32$$

$$°C = 5/9(°F - 32)$$

Derived SI Units

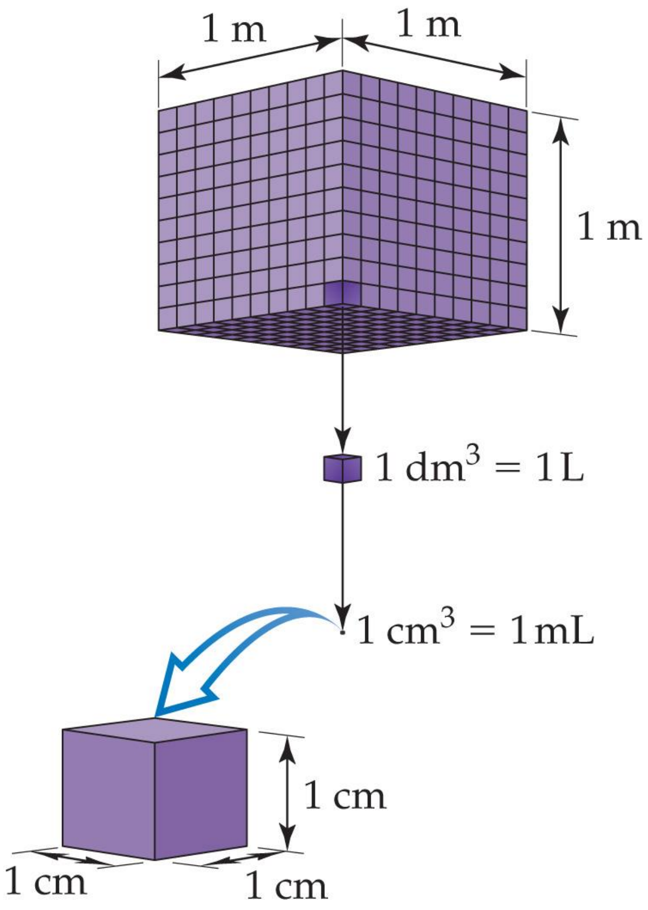
Volume

- Note that volume is not a base unit for SI; it is derived from length (m × m × m = m^3).

- The most commonly used metric units for volume are the liter (L) and the milliliter (mL).

✓A liter is a cube 1 decimeter (dm) long on each side.

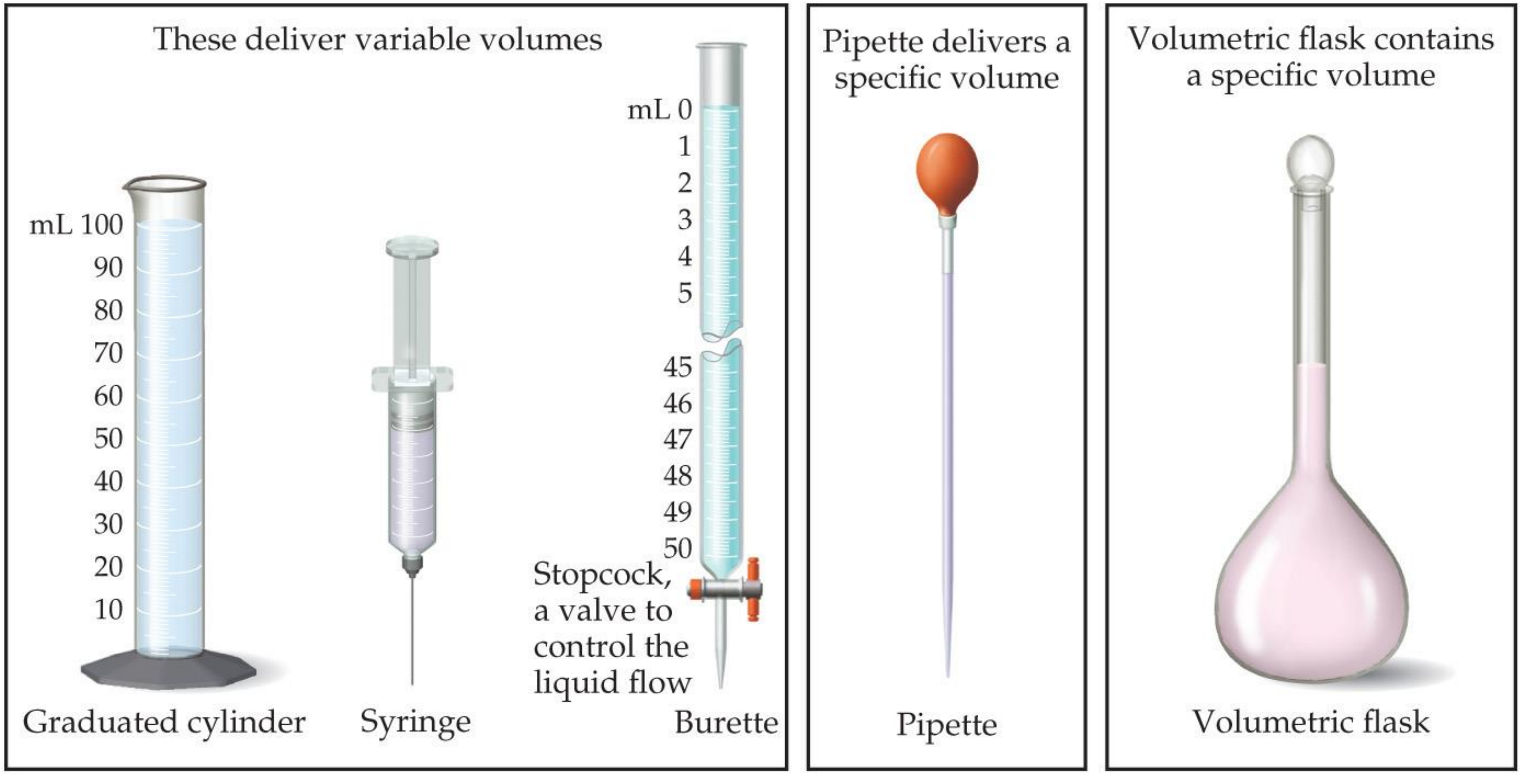
✓A milliliter is a cube 1 centimeter (cm) long on each side, also called 1 cubic centimeter (cm × cm × cm = cm^3).



Derived SI Units

Volume

Common laboratory devices used to measure the volume of liquid samples.



Derived SI Units

Density

- Defined as the mass of an object per unit volume.
- Density is a physical property of a substance.
- It has units that are derived from the units for mass and volume.
- The most common units are g/mL or g/cm^3.

$$Density = \frac{mass}{volume}$$

Table 1.6 Densities of Selected Substances at 25 °C

Substance	Density (g/cm^3)
Air	0.001
Balsa wood	0.16
Ethanol	0.79
Water	1.00
Ethylene glycol	1.09
Table sugar	1.59
Table salt	2.16
Iron	7.9
Gold	19.32

Uncertainty in Measurement

Two kinds of numbers in scientific work: exact and inexact numbers.

- **Exact** numbers are counted or given by definition. For example, there are 12 eggs in 1 dozen.
- **Inexact** (or **measured**) numbers depend on how they were determined. Scientific instruments have limitations. Some balances measure to ±0.01 g; others measure to ±0.0001g.

Uncertainty in Measurement

Accuracy versus Precision

- **Accuracy** refers to the proximity of a measurement to the true value of a quantity.

- **Precision** refers to the proximity of several measurements to each other.

Good accuracy
Good precision

Poor accuracy
Good precision

Poor accuracy
Poor precision

Significant Figures

- The term **significant figures** refers to digits that were measured.
- When rounding calculated numbers, we pay attention to significant figures so we do not overstate the accuracy of our answers.
- The greater the number of significant figures, the greater is the certainty for the measurement.

How to count significant figures?

1. All nonzero digits are significant.
2. Zeroes between two significant figures are themselves significant.
3. Zeroes at the beginning of a number are never significant.
4. Zeroes at the end of a number are significant if a decimal point is written in the number.

Significant Figures

- When addition or subtraction is performed, answers are rounded to the least significant **decimal place**.

- When multiplication or division is performed, answers are rounded to the number of digits that corresponds to the ***least*** **number of significant figures** in any of the numbers used in the calculation.

- When rounding-off numbers, look at the leftmost digit to be removed:
  - If the leftmost digit removed is less than 5, the preceding number is left unchanged.
  - If the leftmost digit removed is 5 or greater, the preceding number is increased by 1.

Dimensional Analysis

- We use **dimensional analysis** to convert one quantity to another.
- Most commonly, dimensional analysis utilizes **conversion factors** (e.g., 1 in. = 2.54 cm).
- A conversion factor is a factor who has the same quantity for numerator and denominator.
- We can set up a ratio of comparison for the equality either 1 in/2.54 cm *or* 2.54 cm/1 in.

Conversion of a unit to a desired unit

$$Given\ unit\ x\ \frac{desired\ unit}{given\ unit} = desired\ unit$$