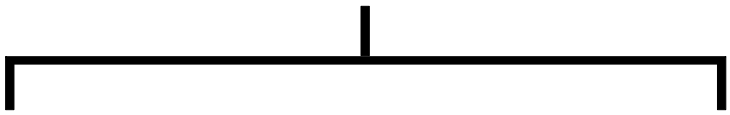
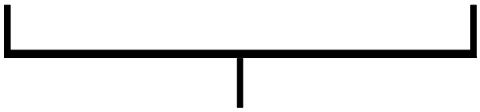
What is Chemistry?

Chemistry - The science dealing with matter and its transformations.

Natural Sciences



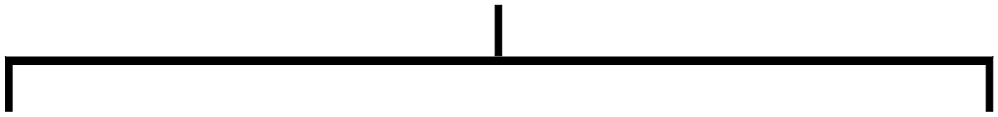
Mathematics ☞ Physics ☞ Chemistry ☞ Biology



Physical Sciences

Chemistry: The Central Science

Physics Chemistry Biology



Physical Inorganic Analytical Organic Bio-Chemistry

Physical	Deals with physical properties and their changes
Inorganic	Deals with substances composed of any elements, but less with those containing both carbon and hydrogen together
Analytical	Deals with determining amounts of substances and their chemical and physical properties
Organic	Deals with substances that contain both carbon and hydrogen, but which may contain certain additional elements
Biochemistry	Deals with the molecules and reactions of life

First Concepts and Definitions of Chemistry

Matter - Anything that has mass and occupies space.

Mass - The measure of the quantity of matter in anything.

Atoms - The fundamental building units of which all matter is composed.

Chemical symbol - One- or two-letter abbreviation for the name of an element. [Learn the names and symbols of the common elements on the hand-out "Some Common Elements".]

Molecule - Chemical entity composed of a certain number of atoms, usually arranged with a particular shape.

Molecular formula - Symbolic representation of the chemical composition of a molecule in which the number of atoms of each element is indicated by a subscript; e.g., H_2O = 2 H atoms + 1 O atom per molecule.

Types of Molecules

Heteronuclear molecule - Composed of atoms of two or more different elements; e.g.,

H_2O (water) CH_4 (methane)
CH_3OH (methyl alcohol) H_2O_2 (hydrogen peroxide)

Homonuclear molecule - Composed of atoms of only one element; e.g.,

H_2 (hydrogen) Cl_2 (chlorine)
S_8 (sulfur) P_4 (phosphorus)

Properties of Matter

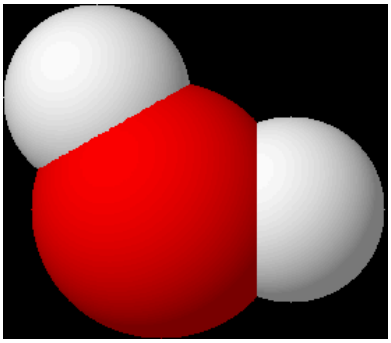
Microscopic properties - Properties of the atoms and molecules (e.g., composition, shape.)

Macroscopic properties - Large scale properties of matter, which are observed for bulk samples.

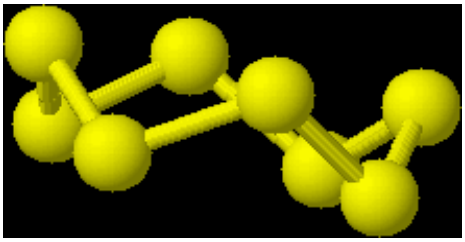
Macroscopic Properties from Microscopic Properties

- Macroscopic properties of matter arise from the microscopic properties of the atoms and molecules of which they are composed.

Water, H_2O, is a colorless liquid that freezes at 0 °C and boils at 100 °C *because* it is composed of bent molecules.



Elemental sulfur, S_8, is a yellow solid *because* it is composed of eight-atom, crown-shaped rings.



States of Matter

State of Matter (Physical State) - Macroscopic form of a sample of matter as a solid, liquid, or gas.

Gas - Physical state in which the sample has no fixed volume or shape, but rather conforms to the volume and shape of its container. A **vapor** is the gas form of a substance that is more frequently encountered as a liquid or solid. The volume of a gas can be compressed or expanded readily.

Liquid - Physical state in which the sample has a fixed volume, but its shape depends upon the portion of the container it occupies. The volume of a liquid cannot be compressed or expanded appreciably.

Solid - Physical state in which the sample has both a fixed volume and shape. The volume of a solid cannot be compressed or expanded appreciably.

Substances

Pure substance (or **substance**) - Matter for which all samples have the same composition, regardless of source. A substance cannot be separated into other substances by physical means (e.g., physical separation, filtration, distillation). Substances may be either elements or compounds.

Element - A substance composed entirely of atoms of one type. A substance that cannot be decomposed into simpler substances by chemical means.

Compound - A substance composed of two or more elements joined in a fixed ratio by weight and having properties different from the individual elements.

Mixtures

Mixture - Combination of two or more substances in which each retains its own chemical composition and properties. Mixtures are separable into their component substances by physical means.

Homogeneous mixture - Mixture with uniform composition and properties throughout. A **solution** is a homogeneous mixture (e.g., sugar + water)

Heterogeneous mixture - Mixture with non-uniform composition having physically distinct parts (e.g., milk, oil-and-vinegar salad dressing).

Types of Properties and Changes

Physical properties - Properties of matter having a particular composition (e.g., color, odor, hardness, density, physical state).

Chemical properties - Properties exhibited as composition changes (e.g., reactivity, flammability).

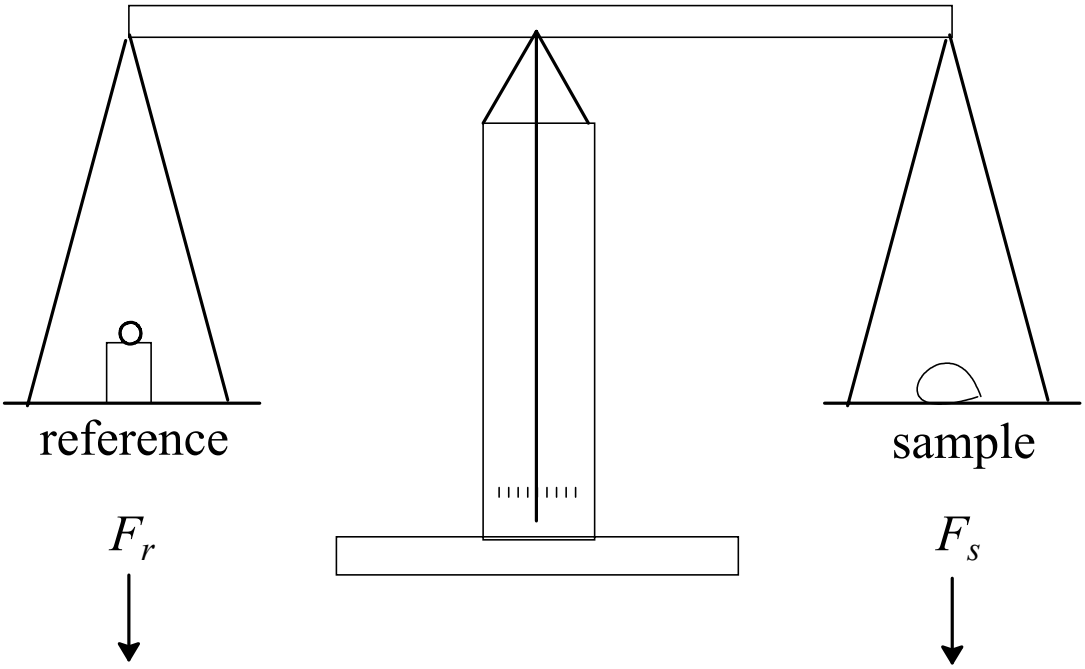
Intensive property - Property independent of the amount of matter in the sample (e.g., density, chemical composition).

Extensive property - Property dependent on the amount of matter in the sample (e.g., mass, volume, weight).

Physical change - Transformation in the state of matter (change of state) with no change in chemical composition (e.g., boiling, freezing).

Chemical change (reaction) - Transformation in the composition of matter.

Determining Mass By Measuring Weight
The Analytical Balance



$$F_r = F_s$$
$$m_r g = m_s g$$
$$\Rightarrow \quad m_r = m_s$$

Antoine Lavoisier
1743 - 1794

"... for nothing is created in the operations either of art or of nature, and it can be taken as an axiom that in every operation an equal quantity of matter exists both before and after the operation, that the quality and quantity of the principles remain the same and that only changes and modifications occur. The whole art of making experiments in chemistry is founded on this principle: we must always suppose an exact equality or equation between the principles of the body examined and those of the products of its analysis."

– Lavoisier, *Traité Élementaire de Chimie*, Paris, 1789, p. 140.

Law of Conservation of Matter

In an ordinary chemical reaction, the total quantity of matter is constant throughout the reaction.

Example: When 1.000 gram of mercury sulfide is heated in air to produce 0.862 gram of mercury metal, 0.137 gram of the air's oxygen reacts and 0.275 gram of sulfur dioxide is produced.

$$HgS + O_2 \rightarrow Hg + SO_2$$
reactants products

Reactant	Amount	Product	Amount
HgS	1.000 g	Hg	0.862 g
O_2	0.137 g	SO_2	0.275 g
Total	1.137 g	Total	1.137 g

Laws, Hypotheses, and Theories

Law - A statement of consistently observed behavior.

Hypothesis - A tentative explanation for observed behavior.

Theory - An explanation of observed behavior, based on an assumed model.

- ☛ Theories change in response to new observations and more sophisticated models.

- ☛ Laws do not change, unless they are based on incomplete observation.

Law of Conservation of Matter and Energy

The total amount of matter and energy in the universe is constant.

- ☛ When matter is converted to energy, as occurs in a nuclear reaction (e.g., nuclear reactor, atomic bomb) the energy produced is given by $E = mc^2$.

- ☛ However, for ordinary chemical reactions, no generally measurable amount of mass is lost as energy, and we may assume that the simpler Law of Conservation of Matter applies.

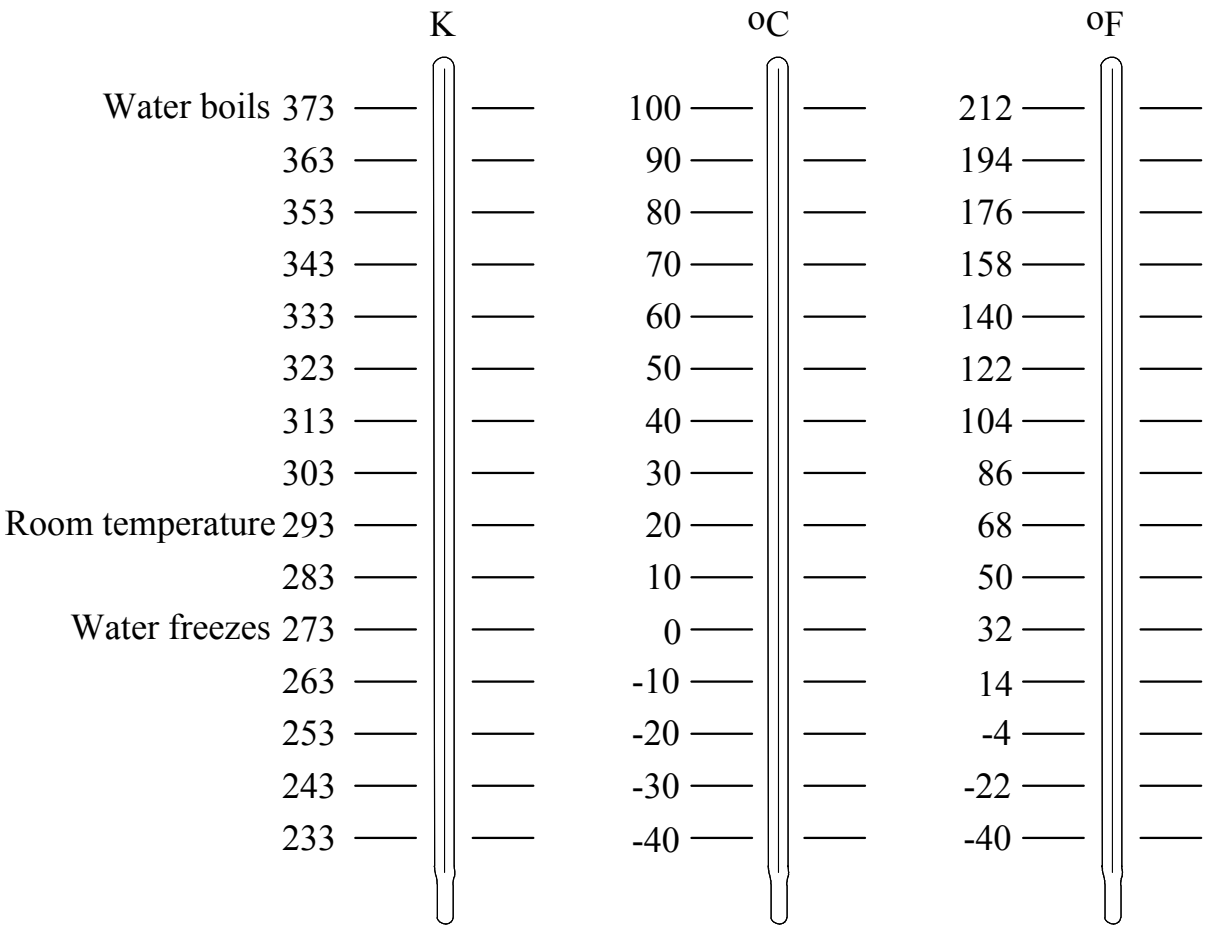
Units of the *Système International d'Unités*
SI Units

Quantity	Unit	Abbrev.
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

Important Prefixes Used with SI Units

Prefix	Abbrev.	$10^{\pm n}$	Example
Mega-	M	10^{6}	Megaherz (MHz)
Kilo-	k	10^{3}	kilogram (kg)
Deci-	d	10^{-1}	deciliter (dL)
Centi-	c	10^{-2}	centimeter (cm)
Milli-	m	10^{-3}	milliliter (mL)
Micro-	μ	10^{-6}	microgram (μg)
Nano-	n	10^{-9}	nanometer (nm)
Pico-	p	10^{-12}	picosecond (ps)
Femto-	f	10^{-15}	femtosecond (fs)

Temperature Scales



$$K = {}^{o}C + 273.15$$

$${}^{o}C = (5/9)({}^{o}F - 32)$$

$${}^{o}F = (9/5){}^{o}C + 32$$

Some Typical Densities

Substance	Density (g/mL)
Air	0.001
Balsa wood	0.11 - 0.14
Cork	0.22 - 0.26
Maple wood	0.62 - 0.75
Paraffin	0.87 - 0.91
Water	1.00
Ebony wood	1.11 - 1.33
Brick	1.4 - 2.2
Quartz	2.65
Lead	11.34
Mercury	13.59