1.2 Chemistry and Matter

Chemistry is the study of matter and the changes that it undergoes. **Matter** is anything that has mass and takes up space. **Mass** is a measurement of the amount of matter in an object. Everything, however, is not made of matter. For example, heat, light, radio waves, and magnetic fields are some things that are not made of matter.

You might wonder why scientists measure matter in terms of mass, and not in terms of weight. Your body is made of matter, and you probably weigh yourself in pounds. However, your **weight** is not just a measure of the amount of matter in your body. Your weight also includes the effect of Earth's gravitational pull on your body. This force is not the same everywhere on Earth. Scientists use mass to measure matter instead of weight because they need to compare measurements taken in different locations.

Matter is made up of particles, called atoms, that are so small they cannot be seen with an ordinary light microscope. The structure, composition, and behavior of all matter can be explained by atoms and the changes they undergo.

Because there are so many types of matter, there are many areas of study in the field of chemistry. Chemistry is usually divided into five branches, as summarized in the table below.

Branches of Chemistry

Branch	Area of emphasis	Examples
Organic chemistry	most carbon-containing chemicals	pharmaceuticals, plastics
Inorganic chemistry	in general, matter that does not contain carbon	minerals, metals and nonmetals, semi-conductors
Physical chemistry	the behavior and changes of matter and the related energy changes	reaction rates, reaction mechanisms
Analytical chemistry	components and composition of substances	food nutrients, quality control
Biochemistry	matter and processes of living organisms	metabolism, fermentation

1.3 Scientific Methods

A **scientific method** is a systematic approach used to answer a question or study a situation. It is both an organized way for scientists to do research and a way for scientists to verify the work of other scientists. A typical scientific method includes making observations, forming a hypothesis, performing an experiment, and arriving at a conclusion.

Scientific study usually begins with observations. Often, a scientist will begin with **qualitative data**—information that describes color, odor, shape, or some other physical characteristic that relates to the five senses. Chemists also use **quantitative data.** This type of data is numerical. It tells how much, how little, how big, or how fast.

Practice Problems

1. Identify each of the following as an example of qualitative data or quantitative data.
   - **a.** taste of an apple
   - **b.** mass of a brick
   - **c.** speed of a car
   - **d.** length of a rod
   - **e.** texture of a leaf
   - **f.** weight of an elephant

A **hypothesis** is a possible explanation for what has been observed. Based on the observations of ozone thinning and CFC buildup in the atmosphere, the chemists Mario Molina and F. Sherwood Rowland hypothesized that CFCs break down in the atmosphere due to the Sun's ultraviolet rays. They further hypothesized that a chlorine particle produced by the breakdown of CFCs could break down ozone.

An **experiment** is a set of controlled observations that test a hypothesis. In an experiment, a scientist will set up and change one variable at a time. A variable is a quantity that can have more than one value. The variable that is changed in an experiment is called the **independent variable.** The variable that you watch to see how it changes as a result of your changes to the independent variable is called the **dependent variable.** For example, if you wanted to test the effect of fertilizer on plant growth, you would change the amount of fertilizer applied to the same kinds of plants. The amount of fertilizer applied would be the independent variable in this experiment. Plant growth would be the dependent variable. Many experiments also include a **control,** which is a standard for comparison; in this case, plants to which no fertilizer is applied.

A **conclusion** is a judgment based on the data obtained in the experiment. If data support a hypothesis, the hypothesis is tentatively affirmed. Hypotheses are never proven; they are always subject to additional research. If additional data do not support a hypothesis, the hypothesis is discarded or modified. Most hypotheses are not supported by data. Whether the hypothesis is supported or not, the data collected may still be useful. Over time, data from many experiments can be used to form a visual, verbal, and/or mathematical explanation—called a **model**—of the phenomenon being studied.

A **theory** is an explanation that has been supported by many experiments. Theories state broad principles of nature. Although theories are the best explanations of phenomena that scientists have at

Data Analysis

2.1 Units of Measurement

You probably know your height in feet and inches. Most people outside the United States, however, measure height in meters and centimeters. The system of standard units that includes the meter is called the metric system. Scientists today use a revised form of the metric system called the Système Internationale d'Unités, or SI.

▶ **Base units** There are seven base units in SI. A **base unit** is a unit of measure that is based on an object or event in the physical world. Table 2-1 lists the seven SI base units, their abbreviations, and the quantities they are used to measure.

Table 2-1

SI Base Units

Quantity	Base unit
Time	second (s)
Length	meter (m)
Mass	kilogram (kg)
Temperature	kelvin (K)
Amount of a substance	mole (mol)
Electric current	ampere (A)
Luminous intensity	candela (cd)

SI is based on a decimal system. So are the prefixes in Table 2-2, which are used to extend the range of SI units.

Table 2-2

Prefixes Used with SI Units

Prefix	Symbol	Factor	Scientific notation	Example
giga	G	1 000 000 000	10^9	gigameter (Gm)
mega	M	1 000 000	10^6	megagram (Mg)
kilo	k	1000	10^3	kilometer (km)
deci	d	1/10	10^{-1}	deciliter (dL)
centi	c	1/100	10^{-2}	centimeter (cm)
milli	m	1/1000	10^{-3}	milligram (mg)
micro	μ	1/1 000 000	10^{-6}	microgram (μg)
nano	n	1/1 000 000 000	10^{-9}	nanometer (nm)
pico	p	1/1 000 000 000 000	10^{-12}	picometer (pm)

Example Problem 2-1
Using Prefixes with SI Units

How many picograms are in a gram?

The prefix *pico-* means 10^{-12}, or 1/1 000 000 000 000. Thus, there are 10^{12}, or 1 000 000 000 000, picograms in one gram.

Practice Problems

1. How many centigrams are in a gram?
2. How many liters are in a kiloliter?
3. How many nanoseconds are in a second?
4. How many meters are in a kilometer?

▶ **Derived units** Not all quantities can be measured using SI base units. For example, volume and density are measured using units that are a combination of base units. An SI unit that is defined by a combination of base units is called a **derived unit.** The SI unit for volume is the liter. A **liter** is a cubic meter, that is, a cube whose sides are all one meter in length. **Density** is a ratio that compares the mass of an object to its volume. The SI units for density are often grams per cubic centimeter (g/cm^3) or grams per milliliter (g/mL). One centimeter cubed is equivalent to one milliliter.