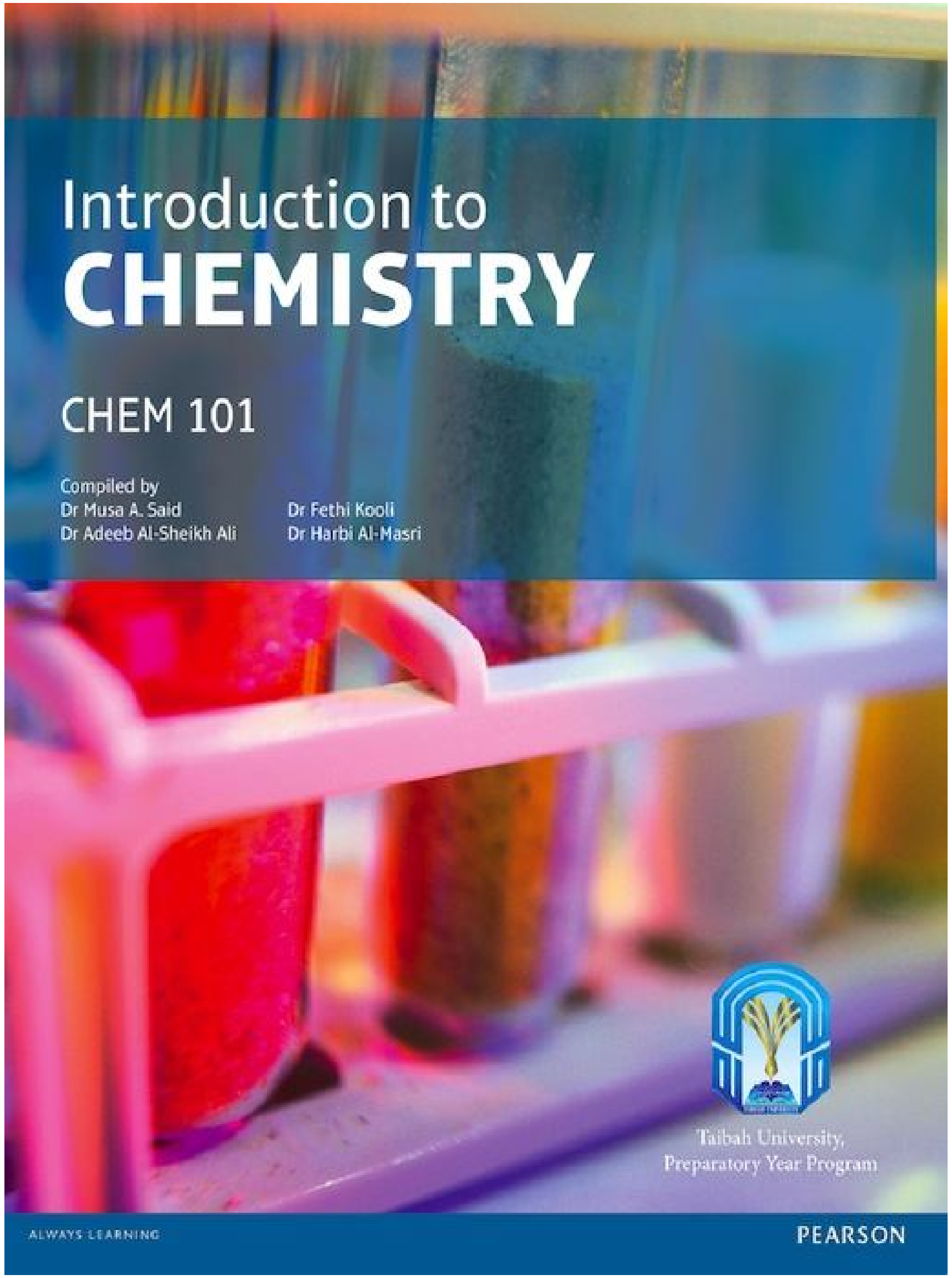


Lecture Presentation

Chapter 1

Introduction: Matter and Measurements

Scientific Terms

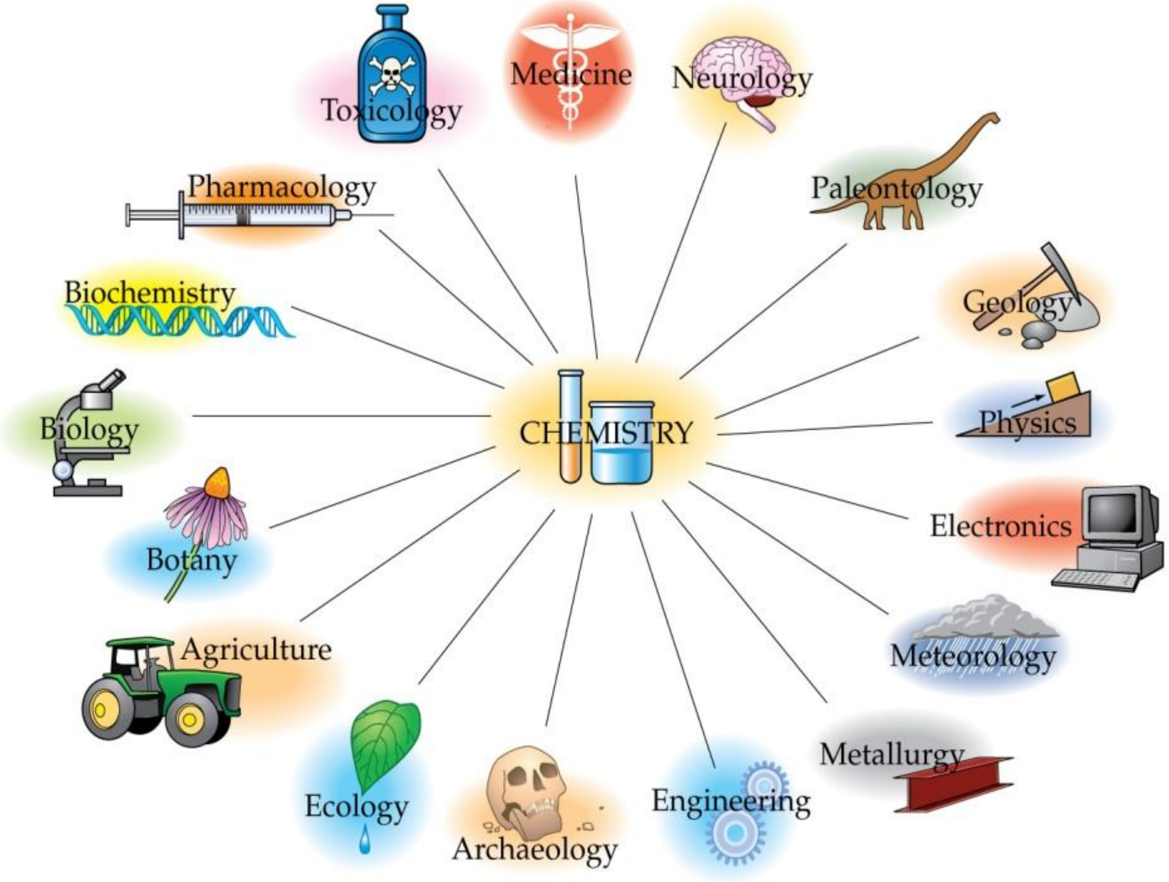
chemistry. The study of matter and its transformations.
atom. is the smallest particle of an element
chemical change. A chemical change is a dissociation, or rearrangement of atoms.
chemical property. Measurement of a chemical property involves a chemical change. For example, determining the flammability of gasoline involves burning it, producing carbon dioxide and water.
compound A compound is a material formed from elements chemically combined in definite proportions by mass.
concentration. Compare with dilution. A measure of the amount of substance present in a unit amount of mixture.
condensation. The conversion of a gas into a liquid is called condensation.
crystallization. The process of forming pure crystals by freezing a liquid, evaporating a solution, or precipitating a solid from solution.
density. Mass of a substance per unit volume.
distillation. Distillation is a technique for separating components of a mixture on the basis of differing boiling points.
ductile. ductility. Compare with malleable.
Capable of being drawn into wire. Metals are typically ductile materials.
element Compare with compound and mixture.
An element is a substance composed of atoms with identical atomic number.
evaporation. vaporization. Conversion of a liquid into a gas.
gas. gases; vapor. Matter in a form that has low density, is easily compressible and expandable. Molecules in a gas move freely and are relatively far apart.
heterogeneous mixture. consisting of more than one pure substance and more than one phase.
homogeneous mixture. consisting of more than one pure substance with properties that do not vary within the sample.

kinetic energy. Compare with potential energy. Associated with motion.
liquid. A state of matter that has a high density and is incompressible compared to a gas.
mass. (m) Is a measure of the tendency of an object to resist acceleration.
matter. Is anything that has mass. Air, water, coffee, fire, human beings, and stars are matter. Light, X-rays, photons, information, and love aren't matter.
molecule. A molecule is a collection of chemically bound atoms with characteristic composition and structure.
physical change. Compare with chemical change.
A change which does not transform one substance into another.
physical property. Measurement of a physical property may change the arrangement but not the structure of the molecules of a material.
pure substance. A sample of matter that cannot be separated into simpler components without chemical change.
solid. Is a relatively dense, rigid state of matter, with a definite volume and shape?
state of matter. There are three common states of matter: gases, liquids, and solids.
Celsius. (°C) Celsius temperature scale;
kelvin. (K): The SI base unit of temperature
meter. (m) The meter is the basic unit of length in the SI system of units
second. (s) is the base unit of time in the SI system of units

A Science for All Seasons

Chemistry is the study of matter and its changes.

Everything we do involves chemistry.



What Do You Think?

– The properties of matter are determined by the properties of molecules and atoms.

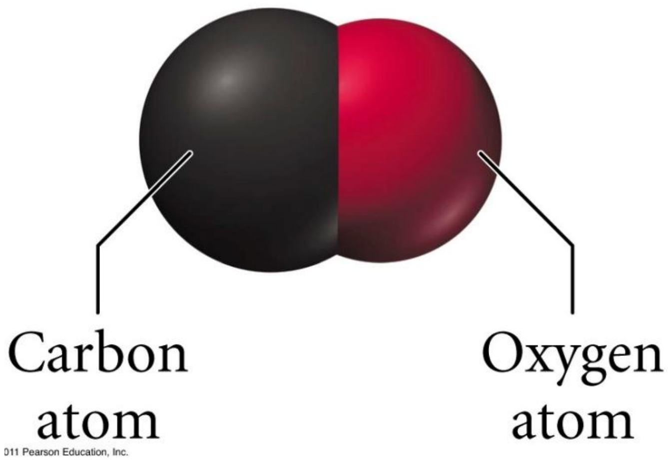
- Atoms and molecules determine how matter behaves; if they were different, matter would be different.

Structure Determines Properties

- The properties of matter are determined by the atoms and molecules that compose it

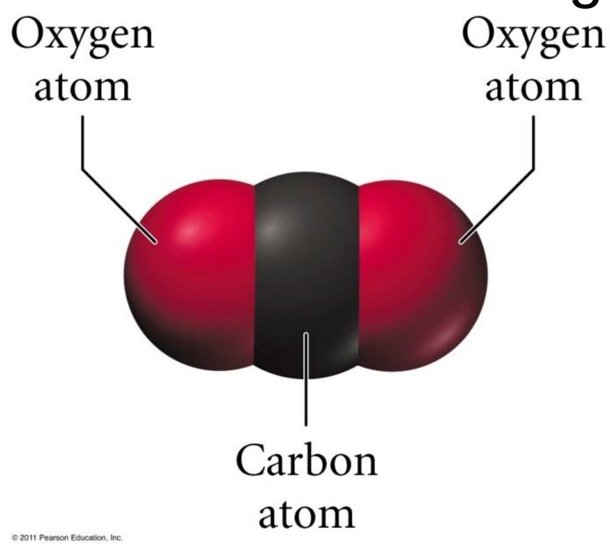
carbon monoxide

1. composed of one carbon atom and one oxygen atom
2. colorless, odorless gas
3. burns with a blue flame
4. binds to hemoglobin



carbon dioxide

1. composed of one carbon atom and two oxygen atoms
2. colorless, odorless gas
3. incombustible
4. does not bind to hemoglobin



Atoms and Molecules

- **Atoms** are the submicroscopic particles that constitute the fundamental building blocks of ordinary matter.

- Free atoms are rare in nature; instead they bind together in specific geometrical arrangements to form **molecules**.

Atoms and Molecules

- If we want to understand the substances around us, we must understand the atoms and molecules that compose them—this is the central goal of chemistry.
  - **Chemistry is the science that seeks to understand the behavior of matter by studying the behavior of atoms and molecules.**

Matter

- **Matter** is anything that occupies space and has mass.
  - Your textbook, your desk, your chair, and even your body are all composed of matter.
- We can classify matter according to its **state** (its physical form) and its **composition** (the basic components that make it up).

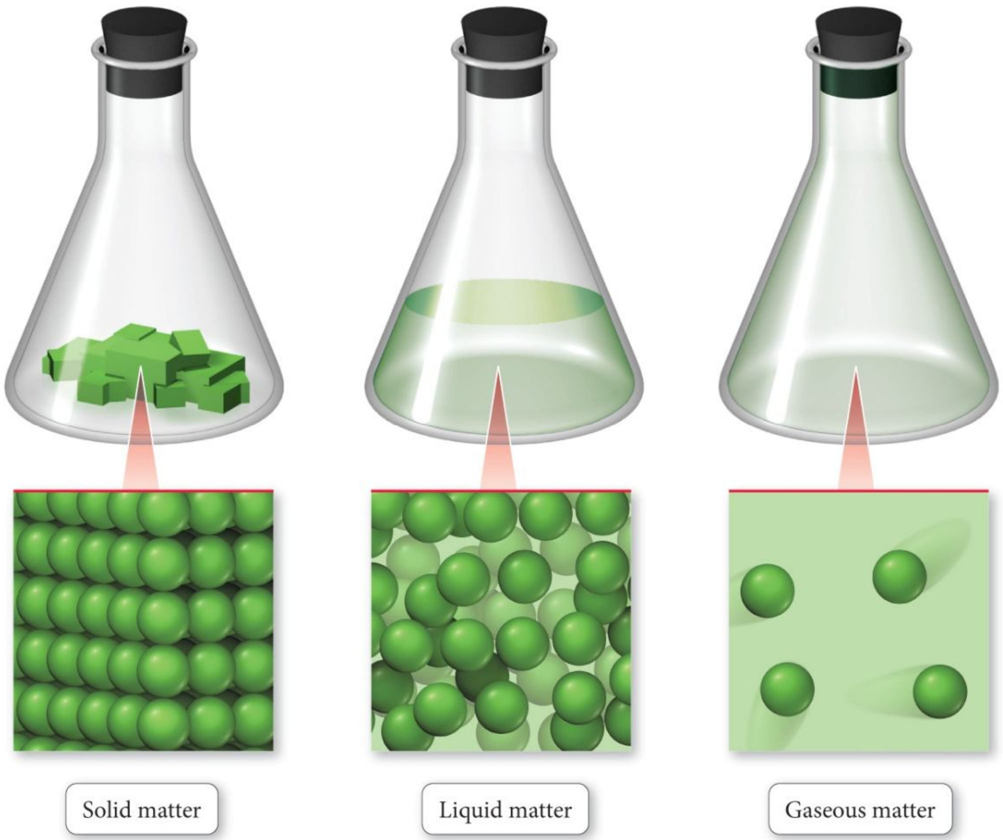
The States of Matter

- **Matter** can be classified as solid, liquid, or gas based on what properties it exhibits.

- The state of matter changes from solid to liquid to gas with increasing temperature.

Structure Determines Properties

- The atoms or molecules have different structures in solids, liquids, and gases—leading to different properties.

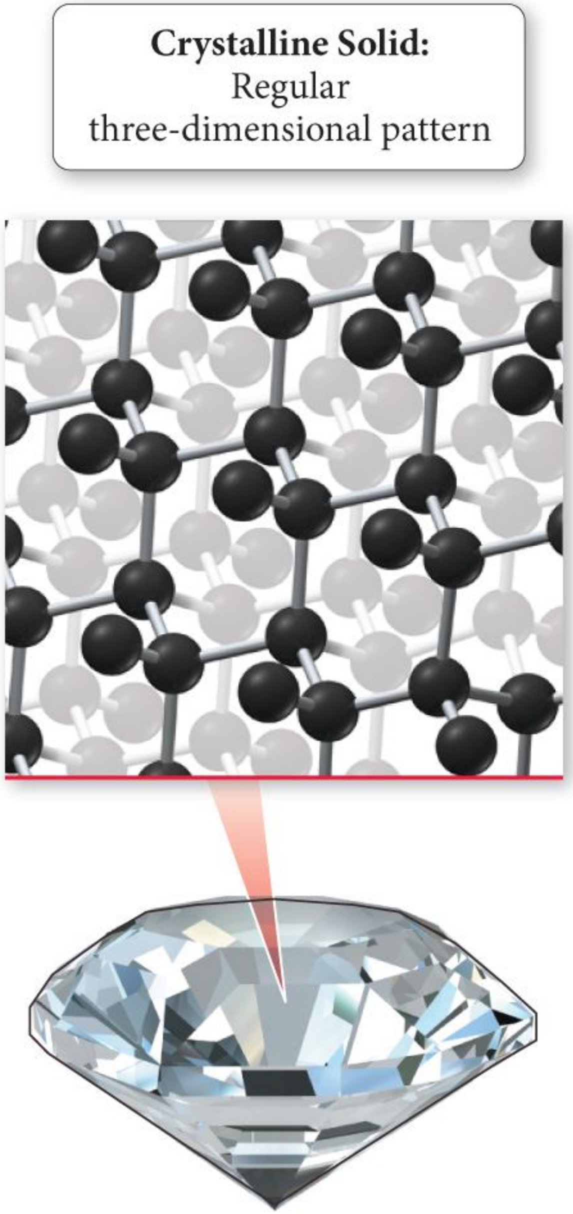


Solid Matter

- In *solid matter*, atoms or molecules pack close to each other in fixed locations.
- Although the atoms and molecules in a solid vibrate, they do not move around or past each other.
- Consequently, a solid has a fixed volume and rigid shape.
    - Ice, aluminum, and diamond are good examples of solids.

Solid Matter

- Solid matter may be **crystalline**—in which case its atoms or molecules are in patterns with long-range, repeating order.
  - Table salt and diamond are examples of solid matter.
- Others may be **amorphous**, in which case its atoms or molecules do not have any long-range order.
  - Examples of *amorphous* solids include glass and plastic.



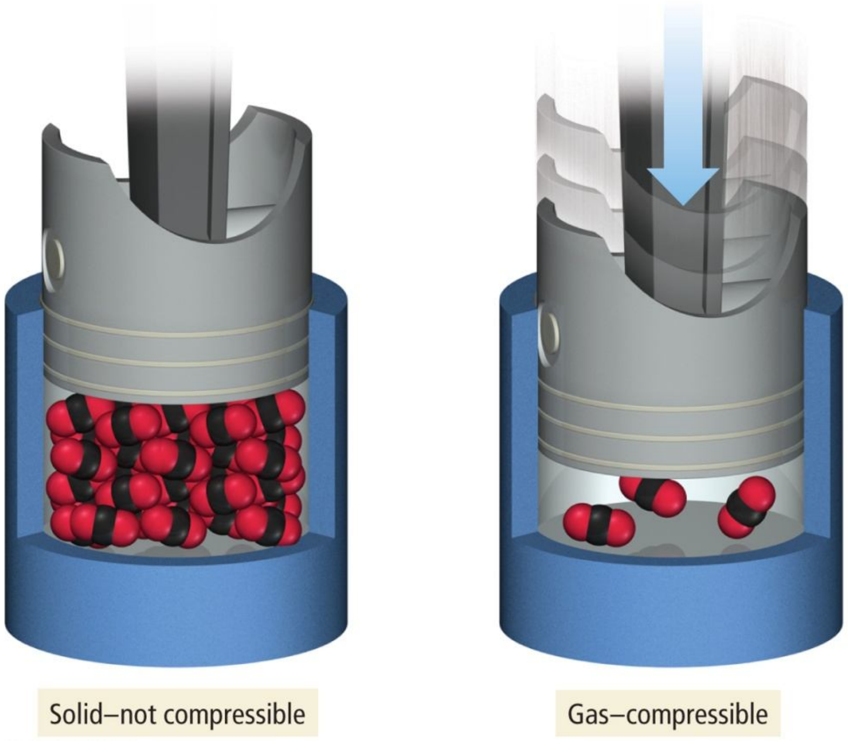
Diamond
C (*s*, diamond)

Liquid Matter

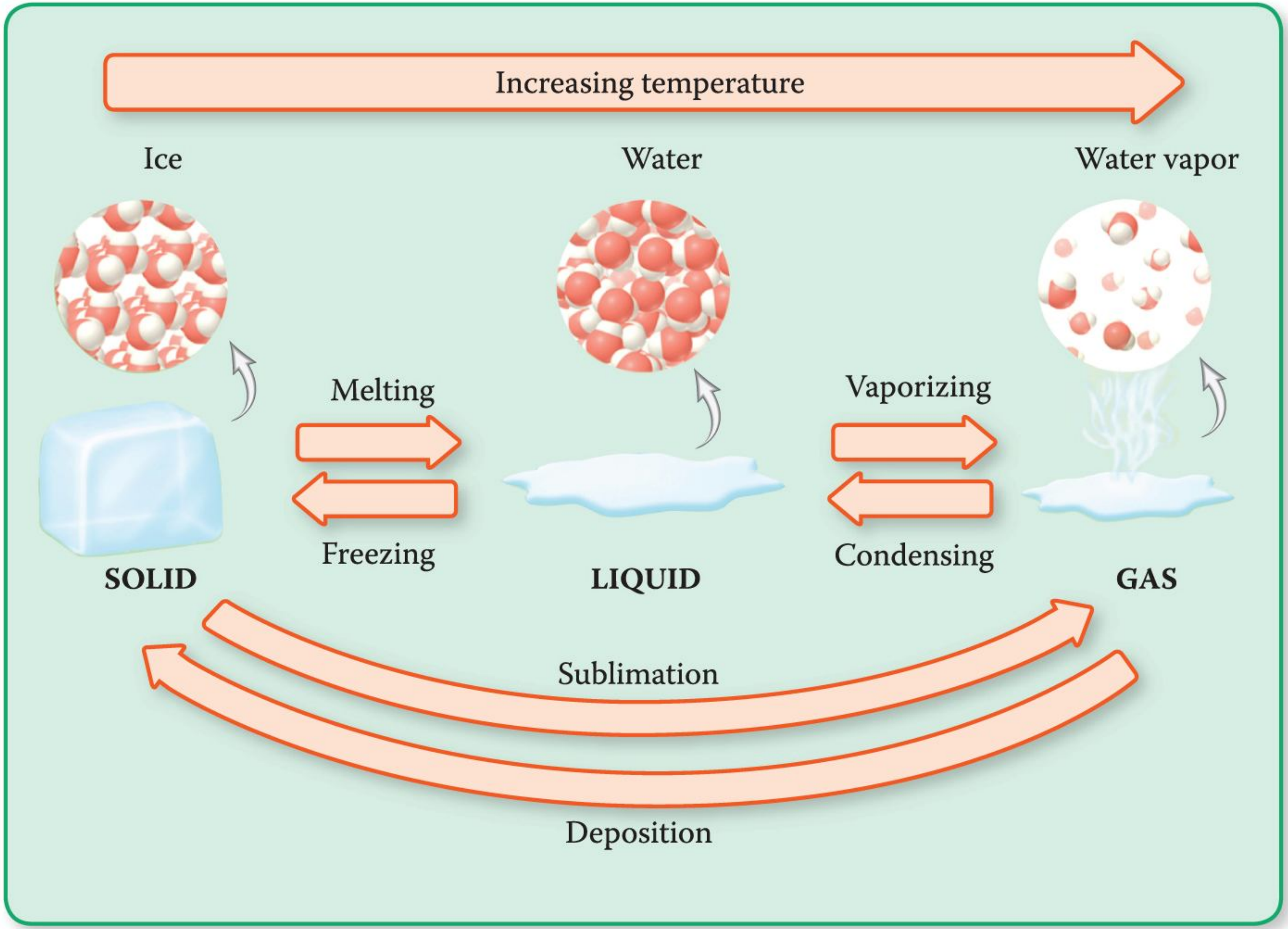
- In *liquid matter*, atoms or molecules pack about as closely as they do in solid matter, but they are free to move relative to each other.
- Liquids have fixed volume but not a fixed shape.
- Liquids' ability to flow makes them assume the shape of their container.
  - Water, alcohol, and gasoline are all substances that are liquids at room temperature**.**

Gaseous Matter

- In *gaseous matter*, atoms or molecules have a lot of space between them.
- They are free to move relative to one another.
- These qualities make gases *compressible*.



Summary of State Changes



Classifications of Matter

- Matter can be divided into two classes:
  1. Mixtures
  2. Pure substances
- ***Mixtures*** are composed of more than one substance and can be *physically* separated into its component substances.
- ***Pure substances*** are composed of only one substance and *cannot* be physically separated.

Mixtures

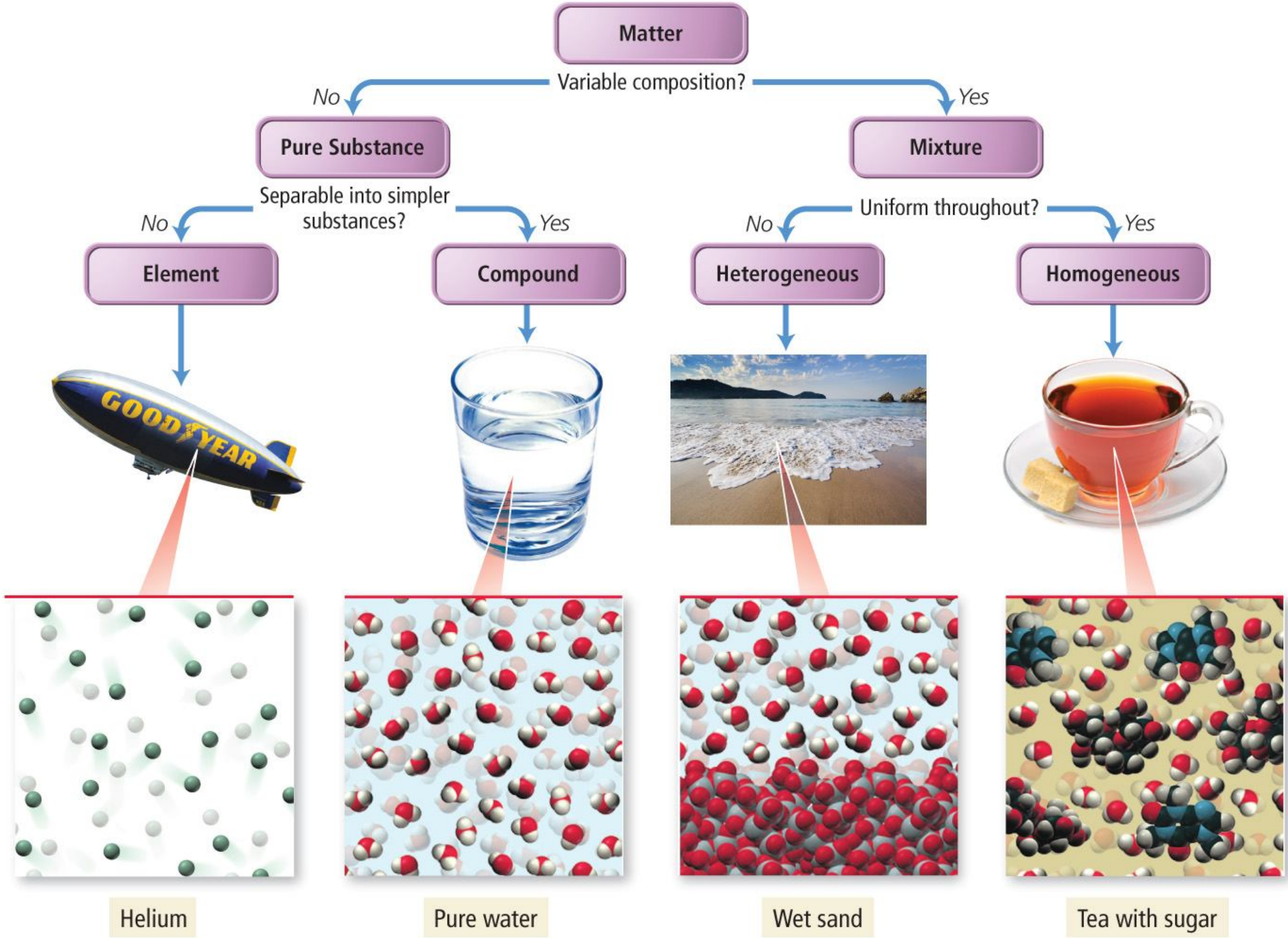
- There are two types of mixtures:
  1. Heterogeneous mixtures
  2. Homogeneous mixtures
- ***Heterogeneous mixtures*** <u>do not have uniform properties throughout</u>.
  - Sand and water is a heterogeneous mixture.
- ***Homogeneous mixtures*** <u>have uniform properties throughout.</u>
  - Salt water is a homogeneous mixture.

Pure Substances

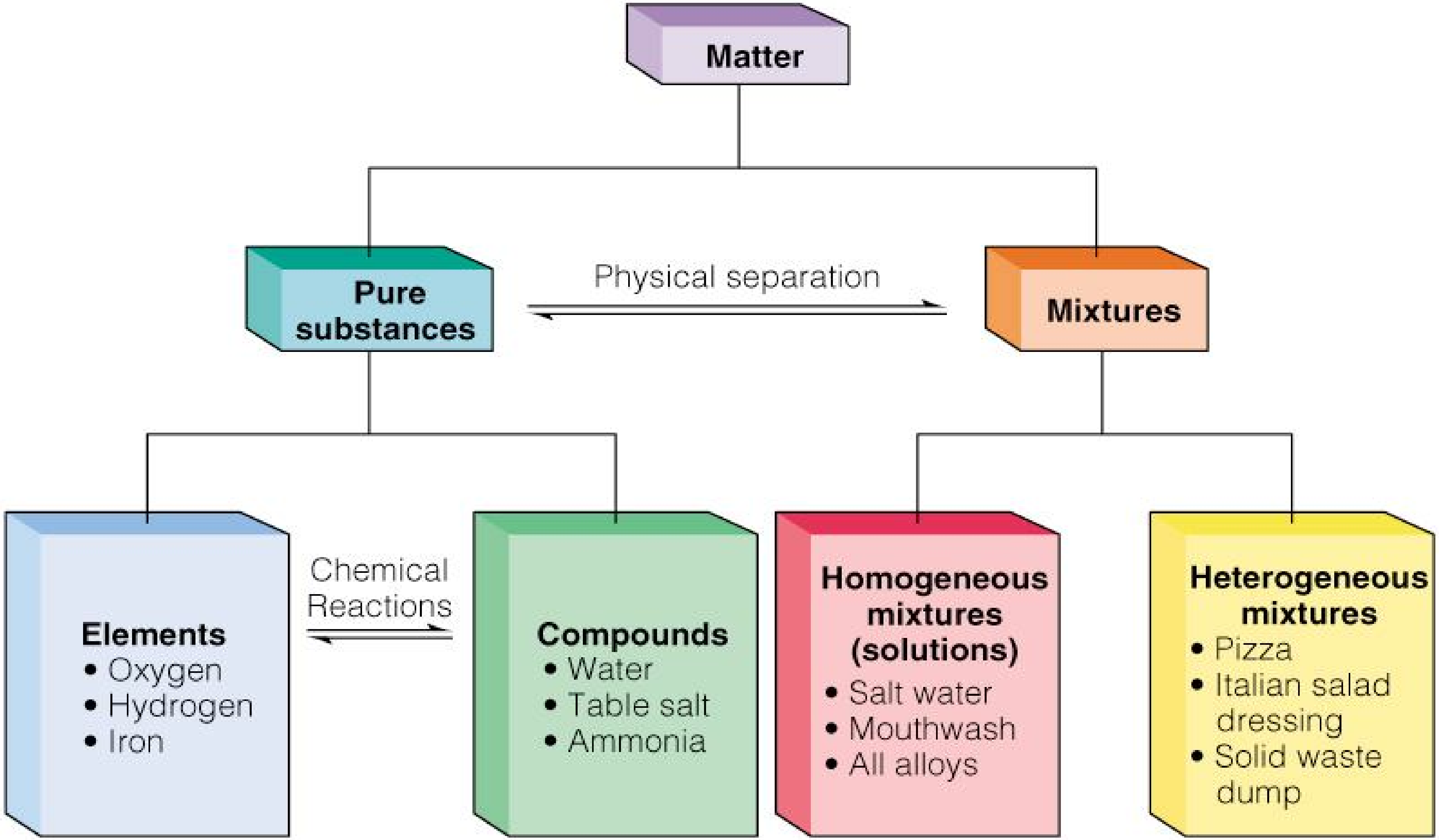
- There are two types of pure substances:
  1. Compounds
  2. Elements
- ***Compounds*** can be *chemically* separated into individual elements.
  - Water is a compound that can be separated into hydrogen and oxygen.
- An ***element*** cannot be broken down further by chemical reactions.

Matter Summary

- Matter can also be classified according to its composition: elements, compounds, and mixtures.



Classification of Matter



Separating Mixtures

- Mixtures are separable because the different components have different physical or chemical properties.

- Various techniques that exploit these differences are used to achieve separation.

- A mixture of sand and water can be separated by **decanting**—carefully pouring off the water into another container.

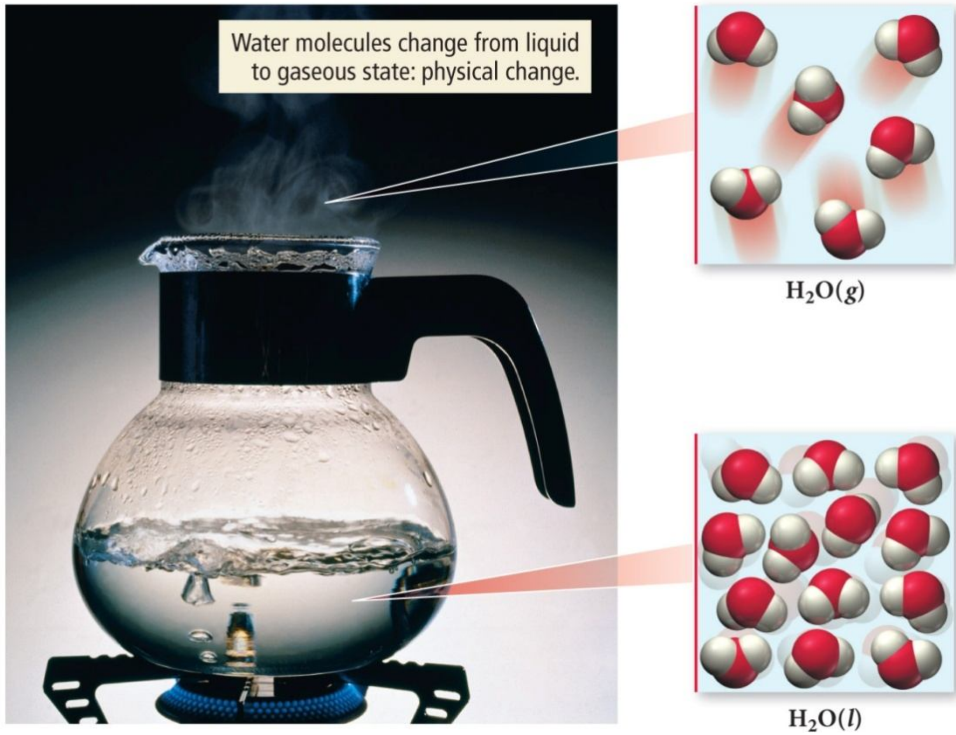
Physical and Chemical Changes

Physical Change:

- Changes that alter only the state or appearance, but not composition, are **physical changes**.
- The atoms or molecules that compose a substance *do not change* their identity during a physical change.

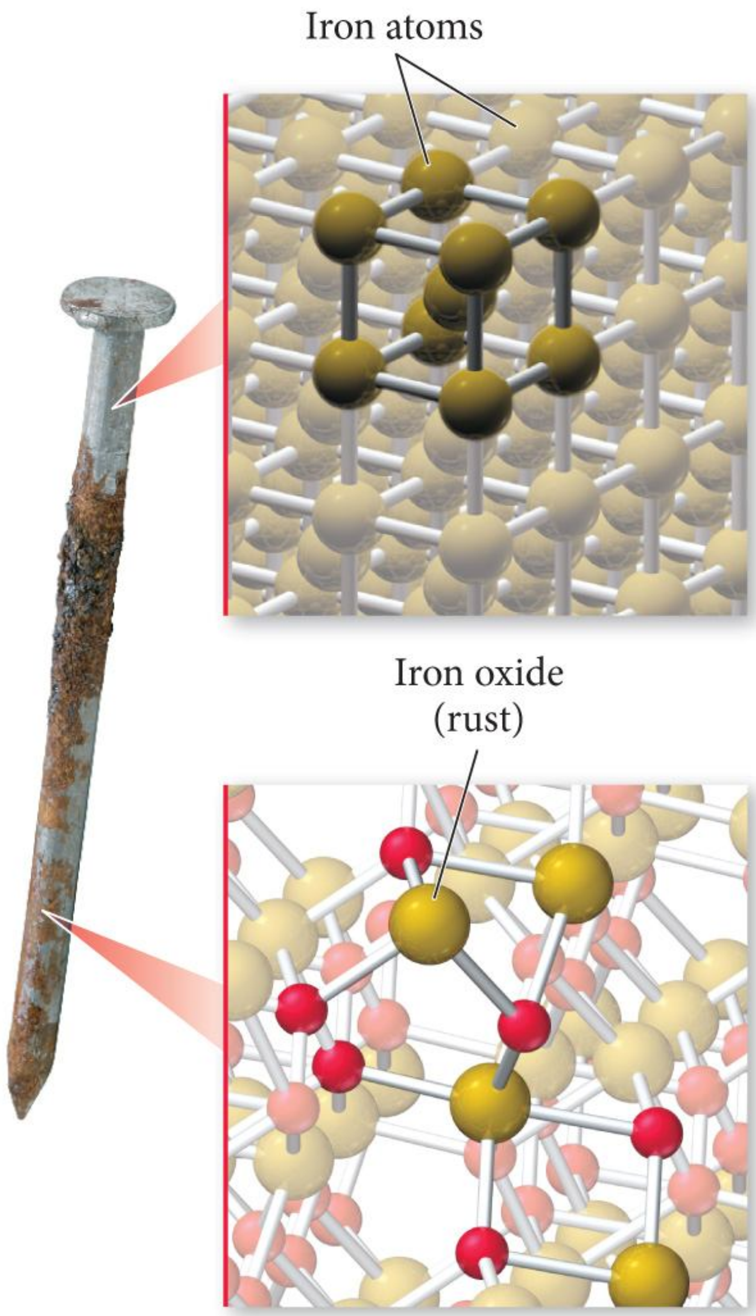
Physical Change

- When water boils, it changes its state from a liquid to a gas.
- The gas remains composed of water molecules, so this is a physical change.



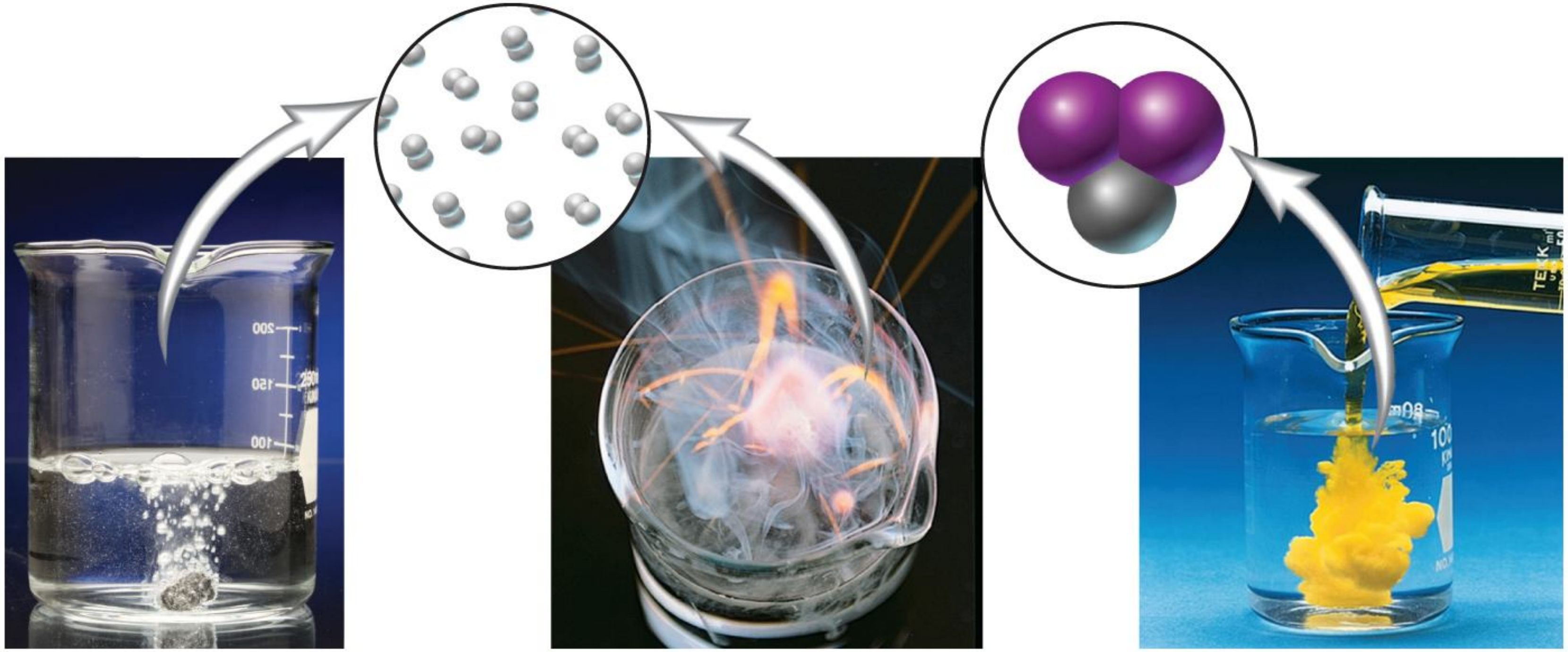
Chemical Change

- Changes that alter the composition of matter are **chemical changes**.
- During a chemical change, atoms rearrange, transforming the original substances into different substances.
- Rusting of iron is a chemical change.



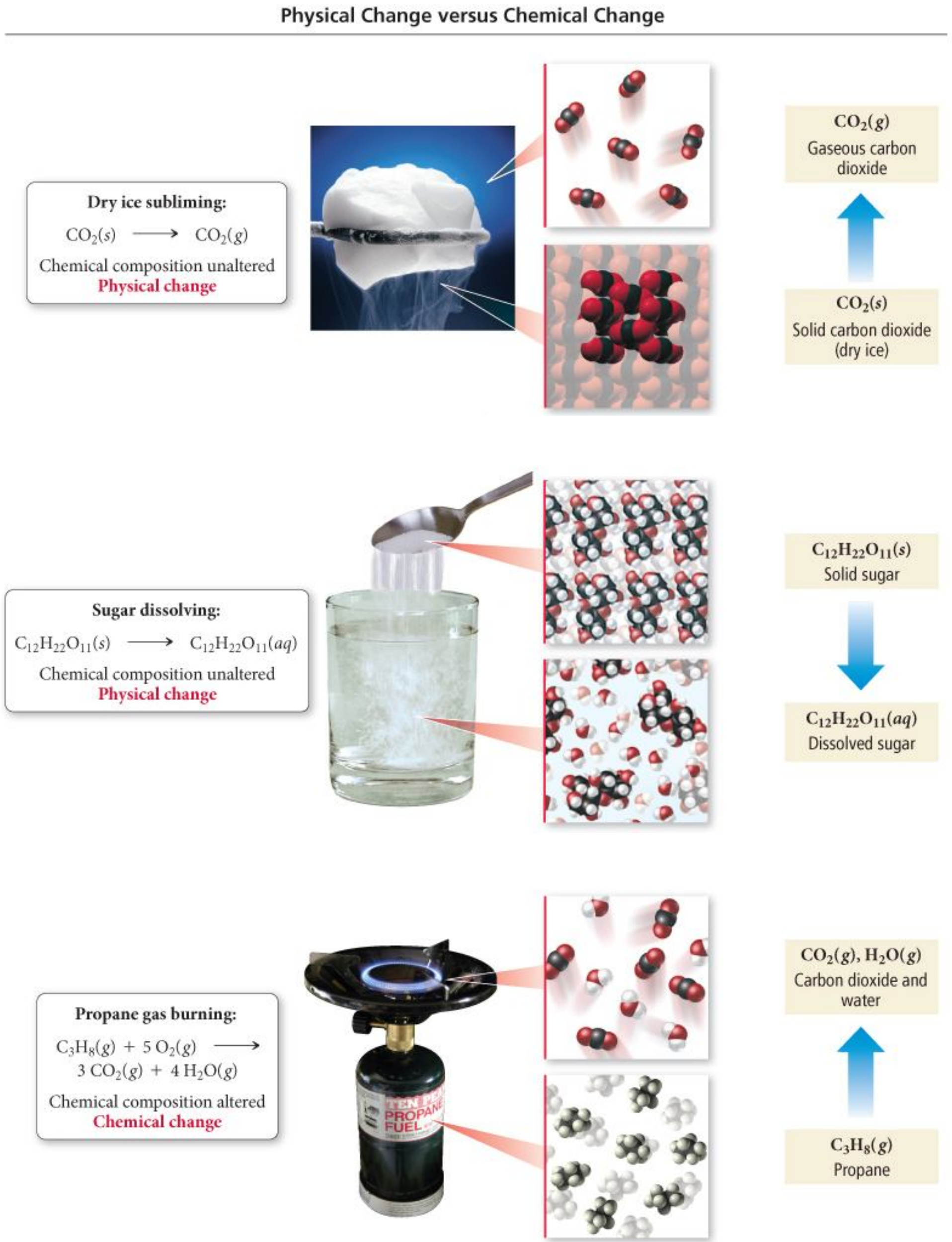
Evidence for Chemical Changes

- Gas release (bubbles)
- Light or release of heat energy
- A permanent color change



(a) (b) (c)

Physical and Chemical Changes



EXAMPLE 1.1 Physical and Chemical Changes and Properties

Determine whether each change is physical or chemical. What kind of property (chemical or physical) is demonstrated in each case?

(a) the evaporation of rubbing alcohol

(b) the burning of lamp oil

(c) the bleaching of hair with hydrogen peroxide

(d) the forming of frost on a cold night

SOLUTION

(a) When rubbing alcohol evaporates, it changes from liquid to gas, but it remains alcohol—this is a physical change. The volatility (the ability to evaporate easily) of alcohol is a physical property.

(b) Lamp oil burns because it reacts with oxygen in air to form carbon dioxide and water—this is a chemical change. The flammability of lamp oil is a chemical property.

(c) Applying hydrogen peroxide to hair changes pigment molecules in hair that give it color—this is a chemical change. The susceptibility of hair to bleaching is a chemical property.

(d) Frost forms on a cold night because water vapor in air changes its state to form solid ice—this is a physical change. The temperature at which water freezes is a physical property.

Physical and Chemical Properties

- A **physical property** is a property that a substance displays without changing its composition.
  - The smell of gasoline is a physical property.
  - Odor, taste, color, appearance, melting point, boiling point, and density are all physical properties.
- A **chemical property** is a property that a substance displays only by changing its composition via a chemical change (or chemical reaction).
  - The flammability of gasoline, in contrast, is a chemical property.
  - Chemical properties include corrosiveness, acidity, and toxicity.

Properties of Matter

- Physical - A characteristic shown by a substance itself, without interacting with or changing into other substances.

- Chemical - A characteristic of a substance appears as it interacts with, or transforms into, other substances.

Chemical Properties

- Does it burn in air?
- Does it decompose when heated?
- Does it react with another substance?
  - Oxygen
  - Acid
  - A metal
- In what ways is it changed by other substances?

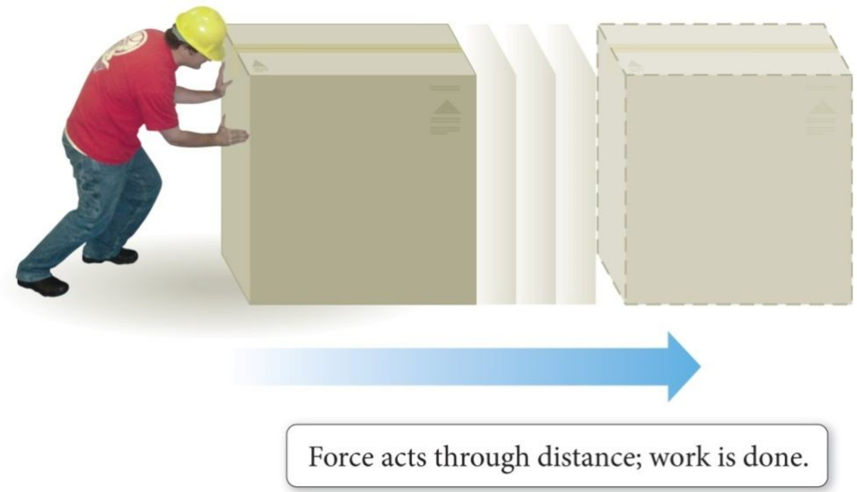
Physical Properties

- Color
- Odor
- Density
- Melting Point
- Boiling Point
- Malleability
- Viscosity
- Hardness
- Metallic Luster
- Ductility

Chemical Properties	
Acidity	Basicity
Inertness	Explosiveness
Inflammable	Flammable
Oxidizing	Reducing

Energy: A Fundamental Part of Physical and Chemical Change

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



- When you push a box across the floor or pedal your bicycle across the street, you have done work.

Potential and Kinetic Energy

- ***Potential energy(mh)***, PE, is stored energy; it results from position or composition.
- ***Kinetic energy(1/2 wc***^{2}), KE, is the energy matter has as a result of its motion.
- Energy can be converted between the two types.
- A boulder at the top of the mountain has *potential energy*; if you push it down the mountain, the *potential energy* is converted to *kinetic energy*.

Law of Conservation of Energy

- Just like matter, energy cannot be created or destroyed, but it can be converted from one form to another.
- This is the ***law of conservation of energy***.
- **There are six forms of energy:**

1. Heat
2. Light
3. Chemical
4. Electrical
5. Mechanical
6. Nuclear

Measurement

We use measurements in everyday life, such as

- walking 2.1 km to campus,
- carrying a backpack with a mass of 12 kg, and
- observing when the outside temperature has reached 22 ^oC.

The Units of Measurement

- In chemistry, **units**—standard quantities used to specify measurements—are critical.
- **The two most common unit systems are as follows:**
  - **Metric system**, used in most of the world
  - **English system**, used in the United States
- Scientists use the **International System of Units (SI)**, which is based on the metric system.
  - The abbreviation *SI* comes from the French, phrase *Système International d'Unités.*

Units in the Metric System

In the metric and SI systems, one unit is used for each type of measurement.

Measurement	Metric	SI
Length	meter (m)	meter (m)
Volume	liter (L)	cubic meter (m^3)
Mass	gram (g)	kilogram (kg)
Temperature	Celsius (°C)	Kelvin (K)
Time	second (s)	second (s)

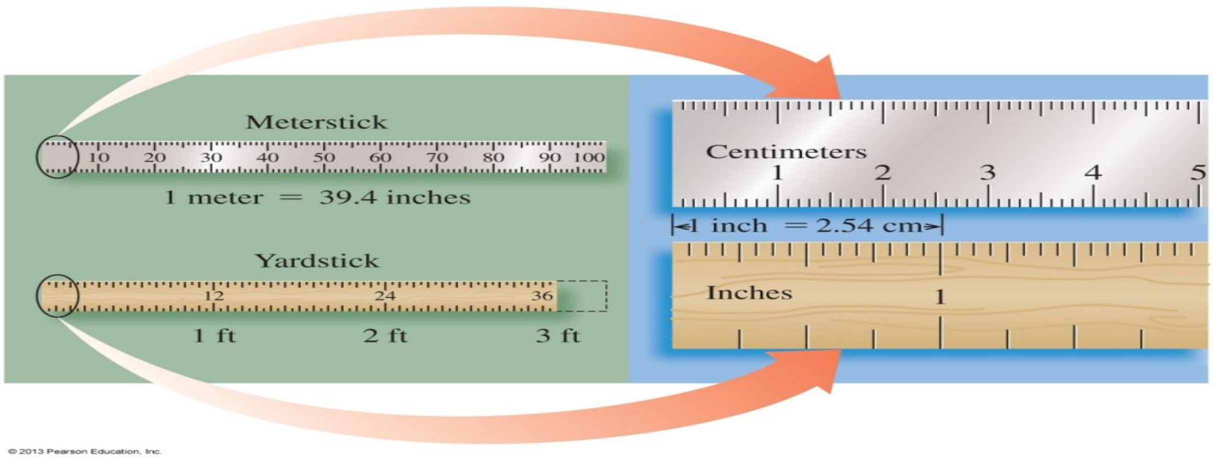
Length Measurement

Length

- is measured using a meter stick.
- uses the unit **meter (m)** in both the metric and SI systems.
- uses centimeters (cm) for smaller units of length.

Useful relationships between units of length

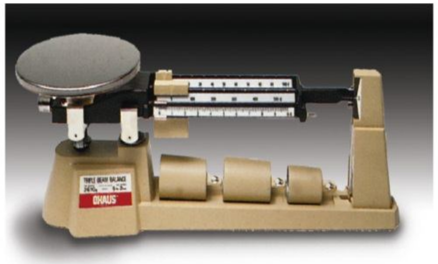
- 2.54 cm = 1 in.
- 1 m = 100 cm
- 1 m = 39.4 in.
- 1 m = 1.09 yd



The Kilogram: A Measure of Mass

- The **mass** of an object is a measure of the quantity of matter within it.

- The SI unit of mass = kilogram (kg).
  - 1 kg = 2.2 lb



(a)

- A second common unit of mass is the gram (g).
  - One gram is 1/1000 kg.

- **Weight** of an object is a measure of the *gravitational pull* on its matter.

(b)

(c)

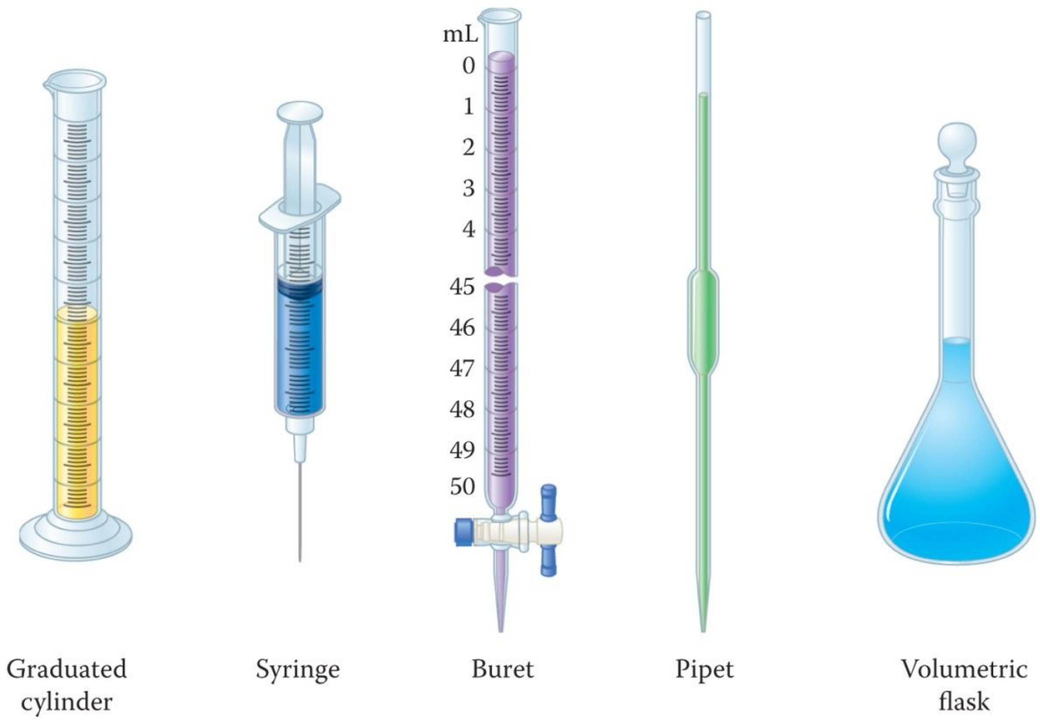
Pounds, Grams, and Kilograms

Useful relationships between units of mass

- 1 kg = 1000 g
- 1 kg = 2.20 lb
- 454 g = 1 lb

Volume Measurements

- Volume is the amount of space occupied by a solid, a liquid, or a gas.
- There are several instruments for measuring volume, including:
  - Graduated cylinder
  - Syringe
  - Buret
  - Pipet
  - Volumetric flask



Quarts, Liters, and Milliliters

Useful relationships between units of volume

- 1 L = 1000 mL
- 1 L = 1.06 qt
- 946 mL = 1 qt
- 1000 L = 1 m^3

Time Measurement

Time measurement

- uses the unit **second (s)** in both the metric and SI systems.
- uses an atomic clock to measure a second.

Days, Hours, Minutes, Seconds

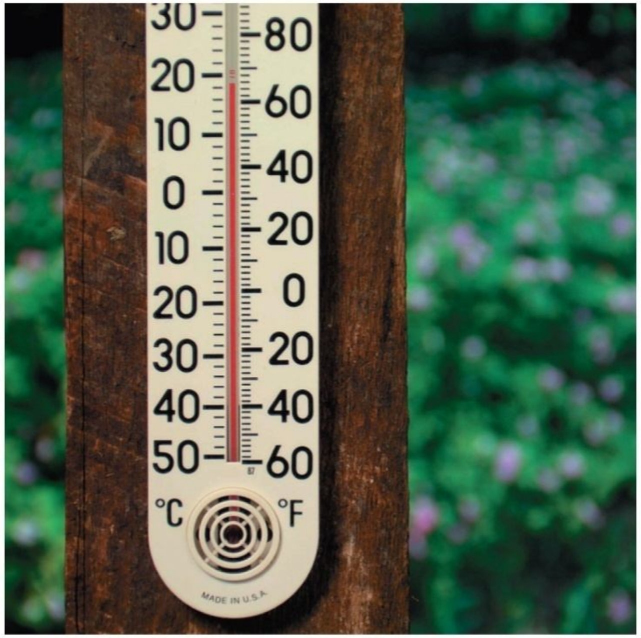
Useful relationships between units of time

- 1 day = 24 h
- 1 h = 60 min
- 1 min = 60 s

Temperature Measurement

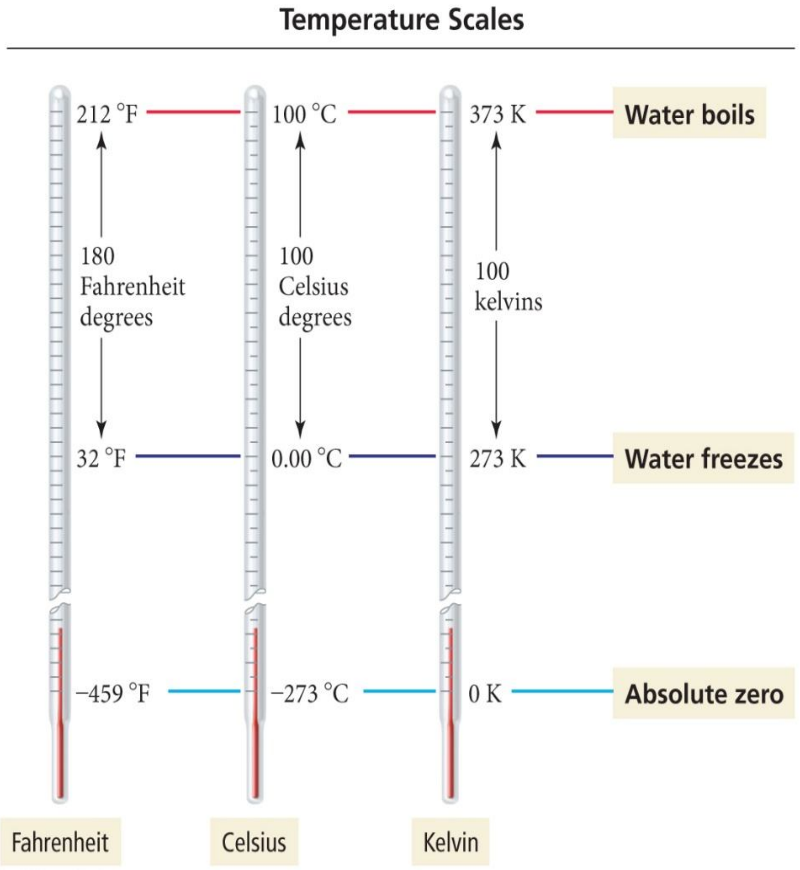
Temperature indicates how hot or cold a substance is, and is

- measured on the **Celsius (°C)** scale in the metric system,
- measured on the **Kelvin (K)** scale in the SI system, and
- 18°C or 64°F on this thermometer.



Temperature Measurements

- Common Units of Temperature:
  - Fahrenheit (^oF)
  - Celsius (^oC)
  - Kelvin (K)
- Boiling Point of Water:
  - 212^{o}F , 100^{o}C, 373.15 K
- Freezing Point of Water
  - 32^{o}F, 0^{o}C, 273.15 K
- Absolute zero is 0 K.
- You can't get any colder than this!



Temperature conversions:

K = °C + 273.15

°C = K – 273.15

$$°F = \left(\frac{9\ °F}{5\ °C} \times °C \right) + 32\ °F$$ **or** $°F = 1.8(°C) + 32$

$$°C = \frac{5\ °C}{9\ °F} \times (°F - 32\ °F)$$ **or** $$°C = \frac{(°F - 32)}{1.8}$$

Example Temperature Conversions

- **Convert 350°F to °C and K.**
- $^oC = (350-32)\ \frac{5}{9}\ = (318)(5/9)\ \ = 177^oC$
- K = 177 + 273 = 450 K

- **Convert -40°C to °F**
- $^oF = (9/5)(-40) + 32 = 9x(-8) + 32 =$
- $-72+32= -40^o$ F

- **Convert 298 K to °C**
- $^oC = 298 - 273 = 25^o$ C

Prefix Multipliers

- The International System of Units uses the **prefix multipliers** shown in Table 1.2 with the standard units.
- These multipliers change the value of the unit by the powers of 10 (just like an exponent does in scientific notation).
- For example, the kilometer has the prefix *kilo* meaning 1000 or 10^3.

Prefixes

A **prefix**

- in front of a unit increases or decreases the size of that unit.
- makes units larger or smaller than the initial unit by one or more factors of 10.
- indicates a numerical value.

Prefix		Value
1 **kilo**meter	=	**10^3** meters
1 **tera**byte	=	**10^{12}** bytes

Metric and SI Prefixes

Prefixes that increase the size of the unit:

TABLE 1.8 Metric and SI Prefixes

Prefix	Symbol	Numerical Value	Scientific Notation	Equality
Prefixes That Increase the Size of the Unit				
peta	P	1 000 000 000 000 000	10^{15}	$1\ Pg = 10^{15}\ g$ $1\ g = 10^{-15}\ Pg$
tera	T	1 000 000 000 000	10^{12}	$1\ Tg = 10^{12}\ g$ $1\ g = 10^{-12}\ Tg$
giga	G	1 000 000 000	10^{9}	$1\ Gm = 10^{9}\ m$ $1\ m = 10^{-9}\ Gm$
mega	M	1 000 000	10^{6}	$1\ Mg = 10^{6}\ g$ $1\ g = 10^{-6}\ Mg$
kilo	k	1 000	10^{3}	$1\ km = 10^{3}\ m$ $1\ m = 10^{-3}\ km$

Metric and SI Prefixes

Prefixes that **decrease** the size of the unit:

Prefixes That Decrease the Size of the Unit

deci	d	0.1	10^{-1}	$1\ \text{dL} = 10^{-1}\ \text{L}$ $1\ \text{L} = 10\ \text{dL}$
centi	c	0.01	10^{-2}	$1\ \text{cm} = 10^{-2}\ \text{m}$ $1\ \text{m} = 100\ \text{cm}$
milli	m	0.001	10^{-3}	$1\ \text{ms} = 10^{-3}\ \text{s}$ $1\ \text{s} = 10^{3}\ \text{ms}$
micro	μ	0.000 001	10^{-6}	$1\ \mu\text{g} = 10^{-6}\ \text{g}$ $1\ \text{g} = 10^{6}\ \mu\text{g}$
nano	n	0.000 000 001	10^{-9}	$1\ \text{nm} = 10^{-9}\ \text{m}$ $1\ \text{m} = 10^{9}\ \text{nm}$
pico	p	0.000 000 000 001	10^{-12}	$1\ \text{ps} = 10^{-12}\ \text{s}$ $1\ \text{s} = 10^{12}\ \text{ps}$
femto	f	0.000 000 000 000 001	10^{-15}	$1\ \text{fs} = 10^{-15}\ \text{s}$ $1\ \text{s} = 10^{15}\ \text{fs}$

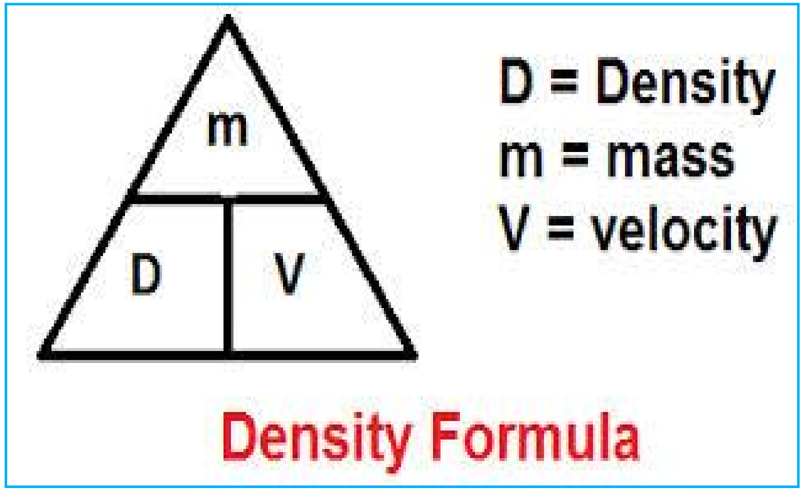
Density

- compares the mass of an object to its volume.
- is the mass of a substance divided by its volume.
- are measured in g/L for gases.
- are measured in g/cm^3 or g/mL for solids and liquids.

Density expression:

$$D = \frac{\text{mass}}{\text{volume}} = \frac{g}{mL} \text{ or } \frac{g}{cm^3} = g/cm^3$$

Note: 1 mL = 1 cm^3



Calculating Density

If a 0.258-g sample of HDL has a volume of 0.215 cm^3, what is the density, in g/cm^3, of the HDL sample?

Step 1 **State the given and needed quantities. Analyze the Problem.**

Given	Need
0.258 g HDL 0.215 cm^3 HDL	density in g/cm^3 of HDL

$$\text{Density} = \frac{\text{mass of substance}}{\text{volume of substance}}$$

$$\text{Density} = \frac{0.258\ \text{g}}{0.215\ \text{cm}^3} = \frac{1.20\ \text{g}}{\text{cm}^3} = 1.20\ \text{g/cm}^3$$

Guide to Problem Solving Using Conversion Factors

If a person weighs 164 lb, what is the body mass in kilograms?

Step 1 **State the given and needed quantities.**
Analyze the Problem

Given	Need
164 lb	kilograms

Step 2 **Write a plan to convert the given unit to the needed unit.**

lb → US–Metric Factor → kilograms

Steps to Solving the Problem

If a person weighs 164 lb, what is the body mass in kilograms?

Step 3 State the equalities and conversion factors.

$$1 \text{ kg} = 2.20 \text{ lb} \qquad \frac{2.20 \text{ lb}}{1 \text{ kg}} \text{ and } \frac{1 \text{ kg}}{2.20 \text{ lb}}$$

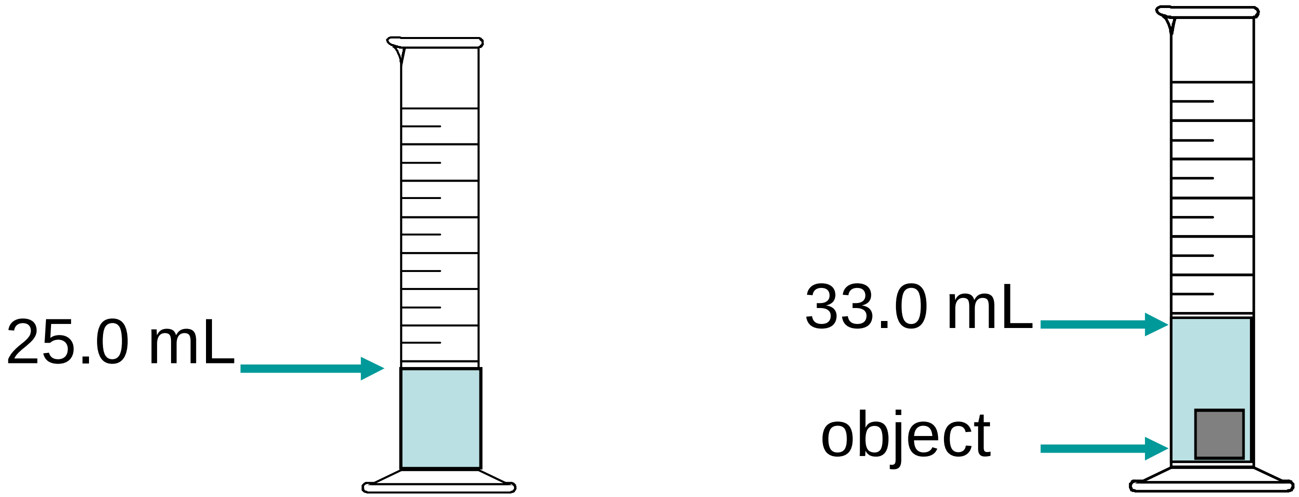
Step 4 Set up the problem to cancel units and calculate the answer.

$$164 \cancel{\text{lb}} \times \frac{1 \text{ kg}}{2.20 \cancel{\text{lb}}} = 74.5 \text{ kg}$$

Density Using Volume Displacement

What is the density (g/cm^3) of a 48.0-g sample of a metal if the level of water in a graduated cylinder rises from 25.0 mL to 33.0 mL after the metal is added?

1) 0.17 g/cm^3
2) 6.0 g/cm^3
3) 380 g/cm^3



Solution

Step 1 State the given and needed quantities.

Given: 48.0 g Volume of water = 25.0 mL

Volume of water + metal = 33.0 mL

Need: Density

Step 2 Write the density expression.

$$\text{Density} = \frac{\text{mass of metal}}{\text{volume of metal}}$$

Solution

Step 3 Express mass in grams and volume in mL or cm^3.

Mass = 48.0 g

Volume of the metal is equal to the volume of water displaced.

Volume of water + metal	= 33.0 mL
− Volume of water	= 25.0 mL
Volume of metal	= 8.0 mL

Solution

Step 4 Substitute mass and volume into the density expression
and calculate the density.

$$\text{Density} = \frac{48.0\ \text{g}}{8.0\ \text{mL}} = \frac{6.0\ \text{g}}{1\ \text{mL}} = 6.0\ \text{g/mL}$$

Learning Check

How many minutes are 2.5 h?

Solution

Given	Need
2.5 h	minutes

$$1\ \text{h} = 60\ \text{min} \qquad \frac{60\ \text{min}}{1\ \text{h}}$$

$$2.5\ \cancel{\text{h}} \times \frac{60\ \text{min}}{1\ \cancel{\text{h}}} = 150\ \text{min}$$

A rattlesnake is 2.44 m long. How many centimeters long is the snake?

$$1\ \text{m} = 100 \qquad \frac{100\ \text{cm}}{1\ \text{m}}\ \text{and}\ \frac{1\ \text{m}}{100\ \text{cm}}$$

$$2.44\ \cancel{\text{m}} \times \frac{100\ \text{cm}}{1\ \cancel{\text{m}}} = 244\ \text{cm}$$

Example: Problem Solving

How many minutes are in 1.6 days?

State the equalities and conversion factors.

1 day = 24 h and 1 h = 60 min

$$\frac{1\,\text{day}}{24\,\text{h}} \text{ and } \frac{24\,\text{h}}{1\,\text{day}} \qquad \frac{1\,\text{h}}{60\,\text{min}} \text{ and } \frac{60\,\text{min}}{1\,\text{h}}$$

Set up problem to cancel units and calculate answer.

$$1.6\,\cancel{\text{days}} \times \frac{24\,\cancel{\text{h}}}{1\,\cancel{\text{day}}} \times \frac{60\,\text{min}}{1\,\cancel{\text{h}}} = 2.3 \times 10^{3}\,\text{min}$$

Chapter Summary

1. What is matter and how is it classified?

Matter has mass and occupies volume.

Matter can be classified as *solid*, *liquid*, or *gas*.

- A solid has a definite volume and shape.
- A liquid has a definite volume, but indefinite shape.
- A gas has neither a definite volume nor shape.

Chapter Summary, *Continued*

1. What is matter and how is it classified?

Matter can be classified by composition as being either *pure* or a *mixture*.

- Every pure substance is either an *element* or a *chemical compound*.
  - Elements are fundamental substances that cannot be chemically changed into anything simpler.
  - A chemical compound can be broken down by chemical change into simpler substances.
- Mixtures are composed of two or more pure substances and can be separated by physical means.

Chapter Summary, *Continued*

2. What kinds of properties does matter have?

***Physical* properties** can be seen without changing the identity of the substance

***Chemical* properties** can only be seen or measured when the substance undergoes a *chemical change*.

Chapter Summary, *Continued*

3. What units are used to measure properties, and how can a quantity be converted from one unit to another?

A *physical quantity* is described by a number and a *unit*.

Units are those of the International System of Units (*SI units*) or the *metric system*.

- Mass is measured in *kilograms* (kg) or *grams* (g).
- Length is measured in *meters* (m).
- Volume is measured in *cubic meters* in the SI system and in *liters* (L) or *milliliters* (mL) in the metric system.
- Temperature is measured in *kelvins* (K) in the SI system and in *degrees Celsius* (°C) in the metric system.

A measurement in one unit can be converted to another unit by multiplying by a *conversion factor* that expresses the exact relationship between the units.

Chapter Summary, *Continued*

4. What are temperature, specific heat, density, and specific gravity?

Temperature is a measure of how hot or cold an object is.

Specific heat is the amount of heat necessary to raise the temperature of 1 g of the substance by 1 °C.

Density relates mass to volume.


Thank you!