

Chapter 1

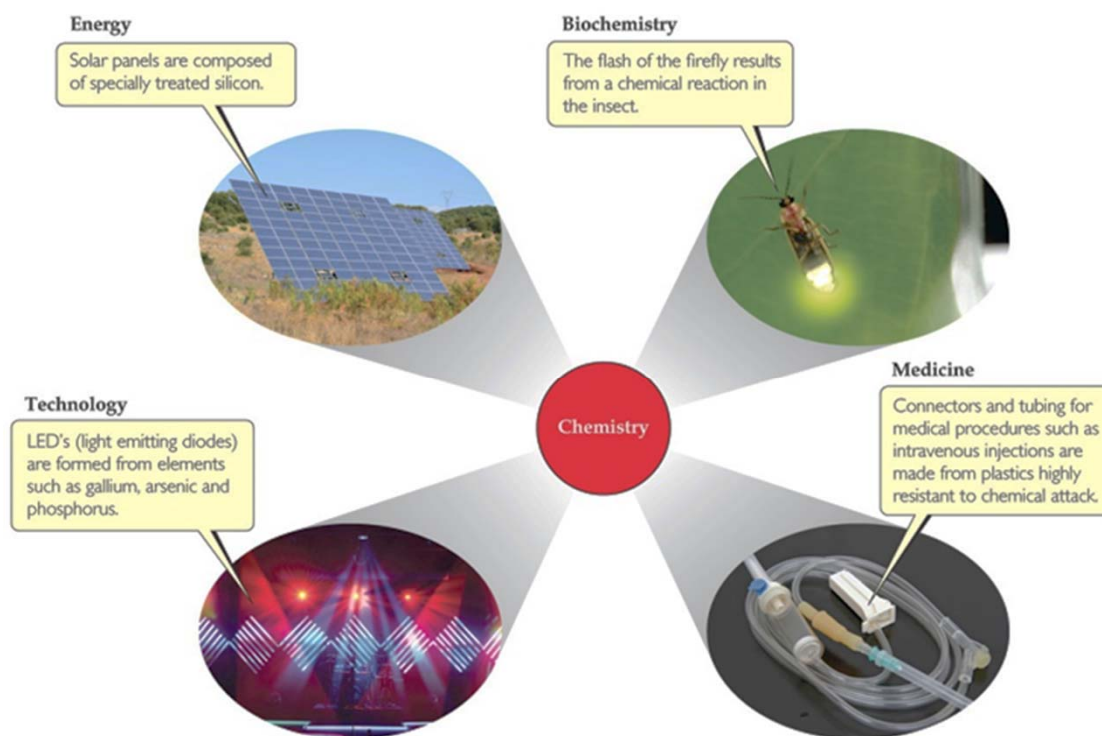
Introduction:

Matter and Measurement

許富銀 (Hsu Fu-Yin)

Why Study Chemistry?

- Chemistry is the study of the properties and behavior of matter.
- Matter has mass and occupies space.



chemists do three things

- (1) make new types of matter: materials, substances, or combinations of substances with desired properties
- (2) measure the properties of matter
- (3) develop models that explain and/or predict the properties of matter.

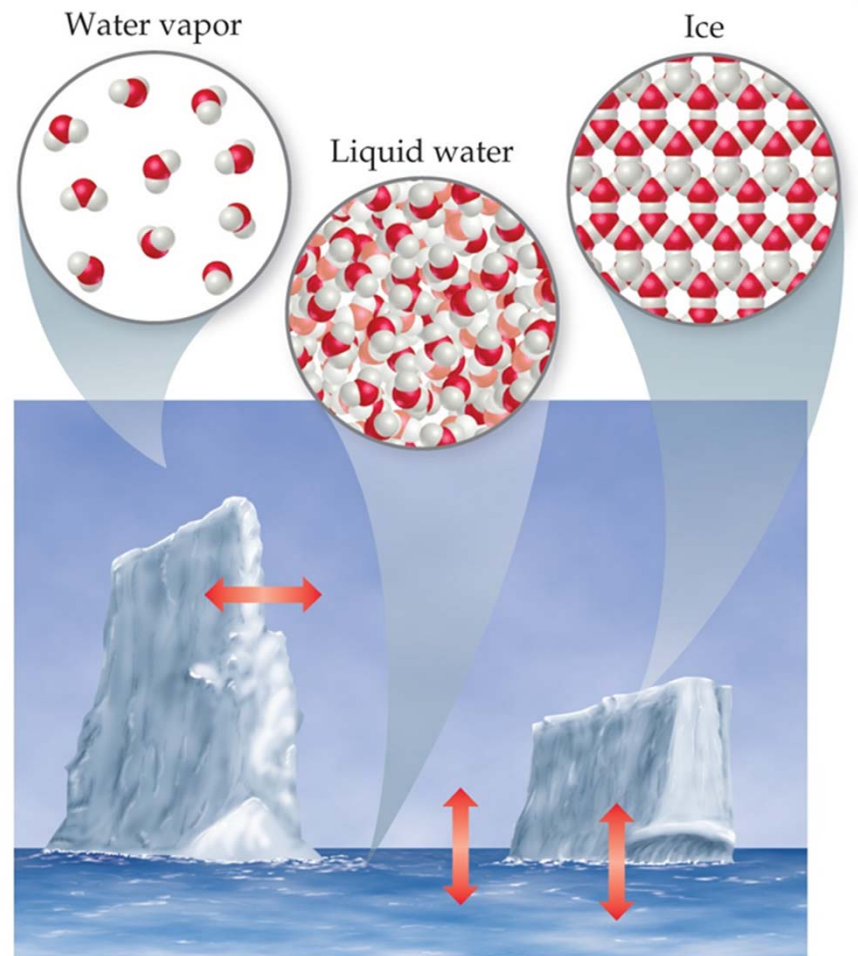
Classifications of Matter

- Matter is typically characterized by
 - (1) its physical state (gas, liquid, or solid)
 - (2) its composition (whether it is an element, a compound, or a mixture).

States of Matter

The three states of matter are

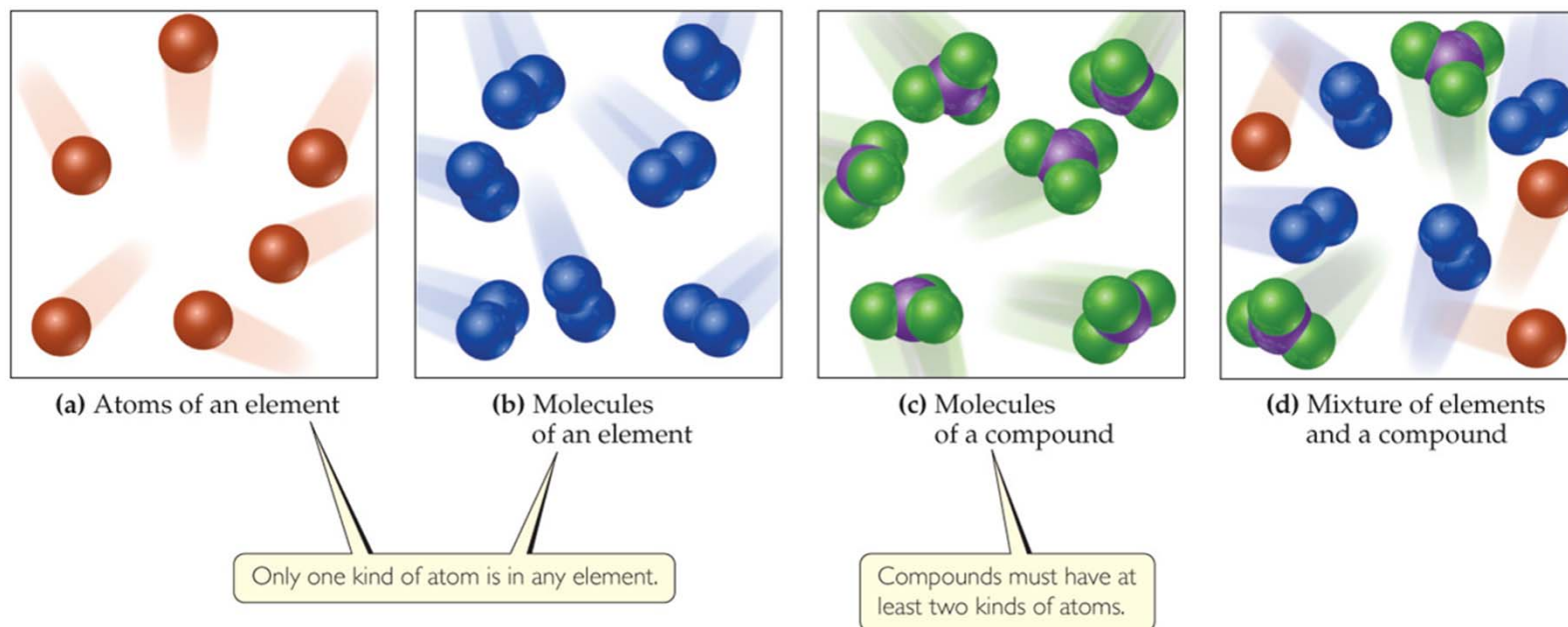
- Solid (s).
- Liquid (l).
- Gas (g).



Classification of Matter Based on Composition

- A pure substance (usually referred to simply as a substance) is matter that has distinct properties and a composition that does not vary from sample to sample
- Elements (元素) are substances that cannot be decomposed into simpler substances.
- Compounds (化合物) are substances composed of two or more elements; they contain two or more kinds of atoms
- Mixtures (混合物) are combinations of two or more substances in which each substance retains its chemical identity

Molecular comparison of elements, compounds, and mixtures.



Atom and Molecule



Hydrogen atom
(written H)



Oxygen atom
(written O)



Water molecule
(written H₂O)

The elements hydrogen and oxygen themselves exist naturally as diatomic (two atom) molecules:

Oxygen molecule



(written O₂)

Hydrogen molecule



(written H₂)

Compounds and Composition

- The Law of Constant Composition (or The Law of Definite Proportions) : Compounds have a definite composition. That means that the relative number of atoms of each element that makes up the compound is the same in any sample.

EX: Two samples of carbon dioxide are decomposed into their constituent elements. One sample produces 25.6 g of oxygen and 9.60 g of carbon, and the other produces 21.6 g of oxygen and 8.10 g of carbon. Show that these results are consistent with the law of definite proportions.

For the first sample:

$$\frac{\text{Mass oxygen}}{\text{Mass carbon}} = \frac{25.6}{9.60} = 2.67 \text{ or } 2.67:1$$

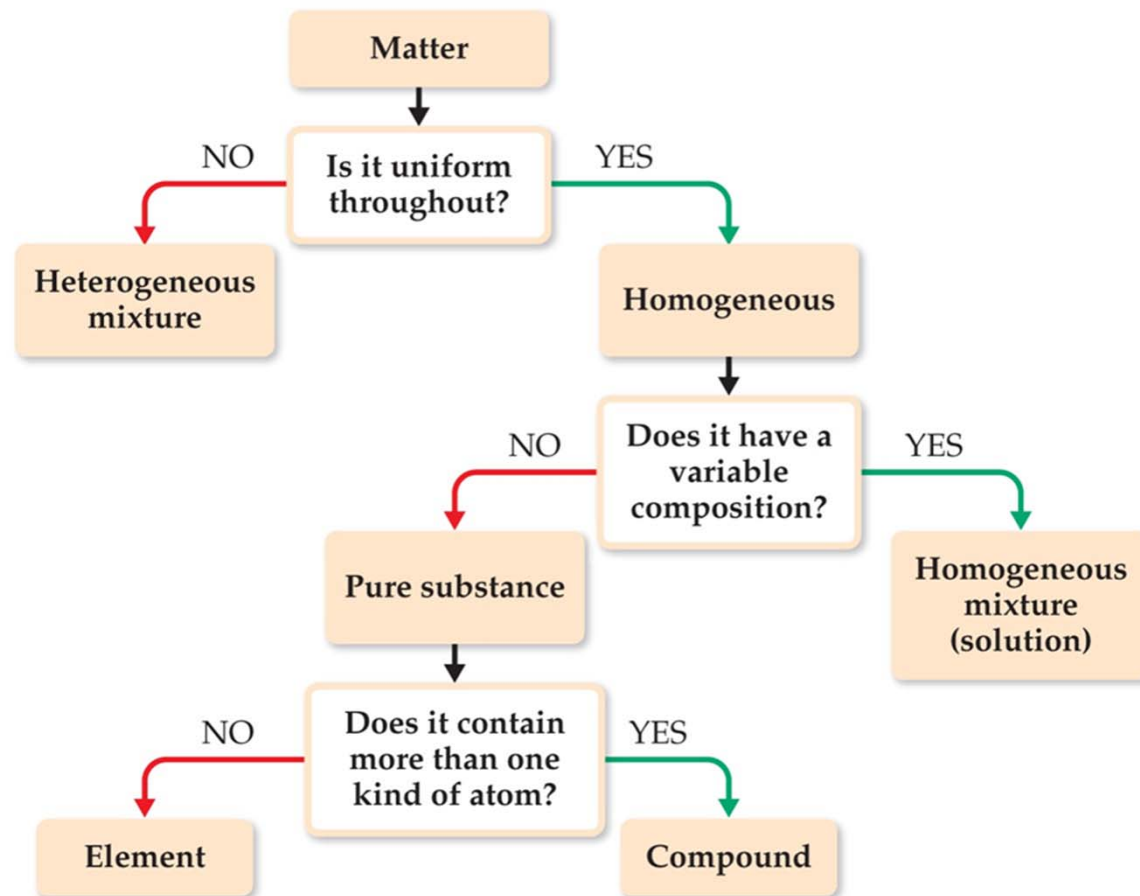
For the second sample:

$$\frac{\text{Mass oxygen}}{\text{Mass carbon}} = \frac{21.6}{8.10} = 2.67 \text{ or } 2.67:1$$

Classification of Matter— Mixtures

- Mixtures can vary in composition throughout a sample (heterogeneous) or can have the same composition throughout the sample (homogeneous).
- Ex:
 - Air is a homogeneous mixture of nitrogen, oxygen, and smaller amounts of other gases.
 - Salt, sugar, and many other substances dissolve in water to form homogeneous mixture
 -

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.

Types of Properties

- 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.

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

Separating Mixtures

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

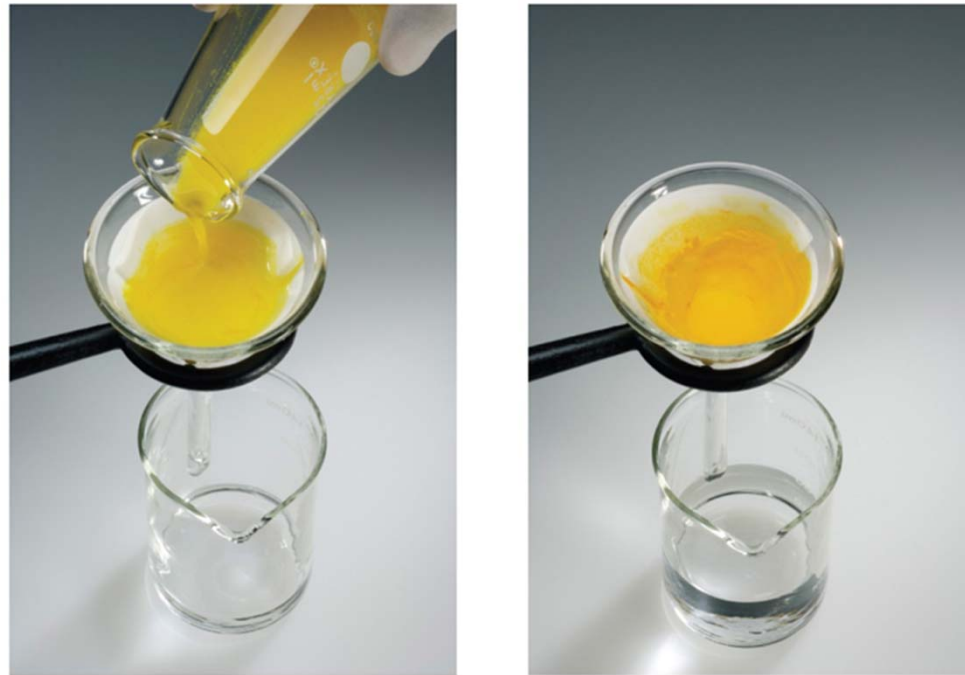
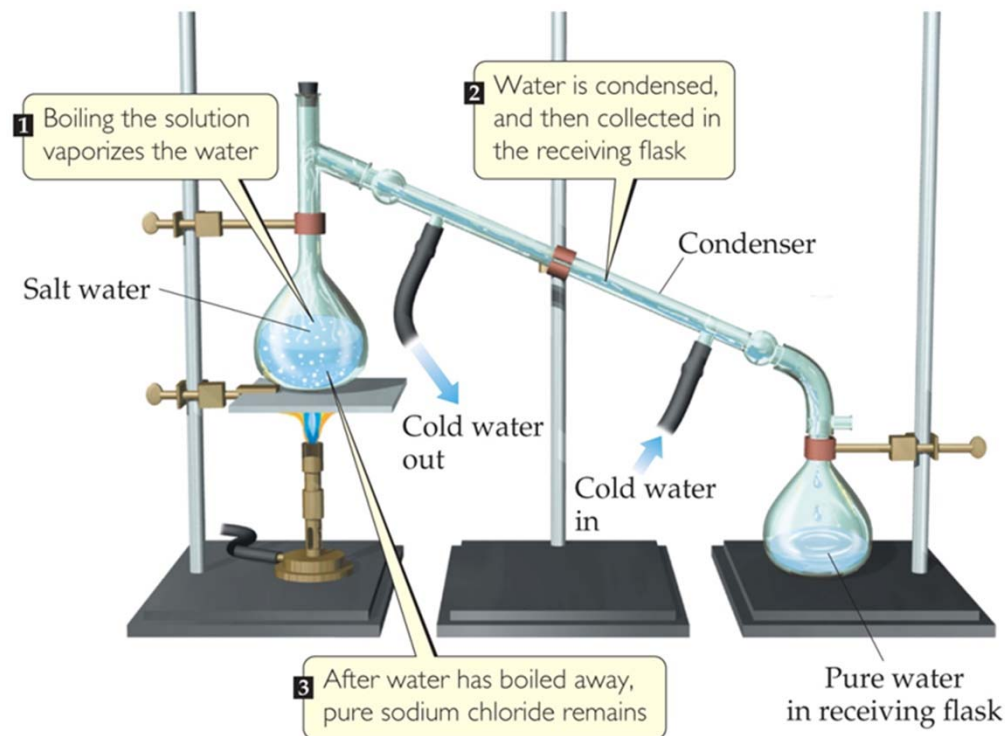


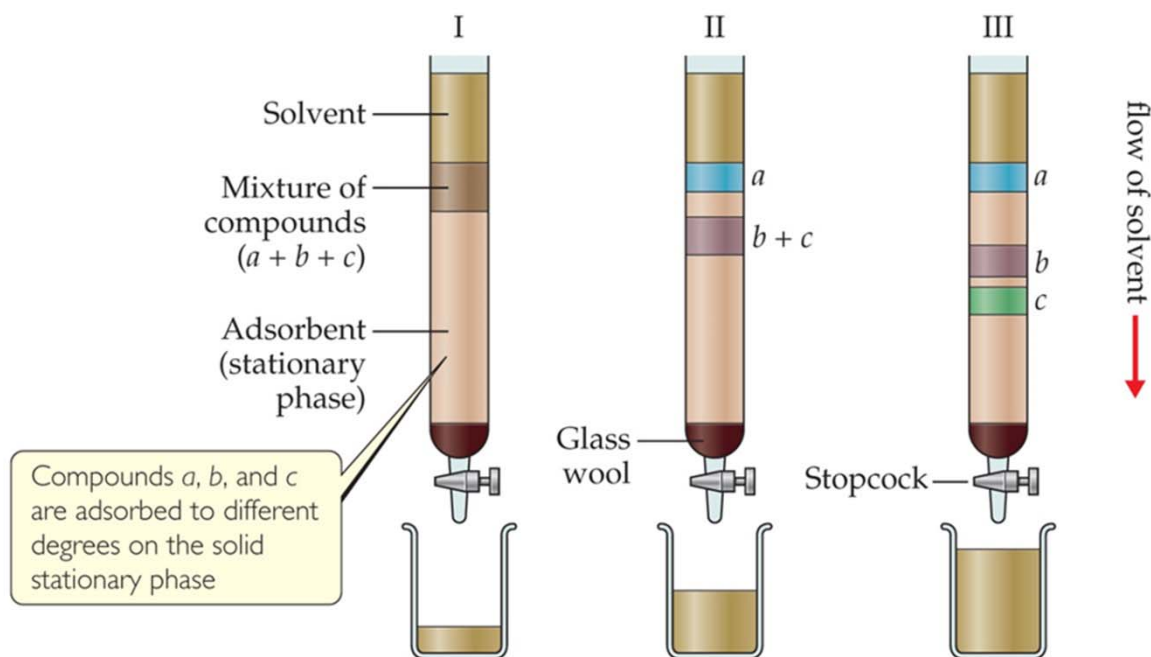
Figure 1.12 Separation by filtration. A mixture of a solid and a liquid is poured through filter paper. The liquid pass through the paper while the solid remains on the paper.

Distillation

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

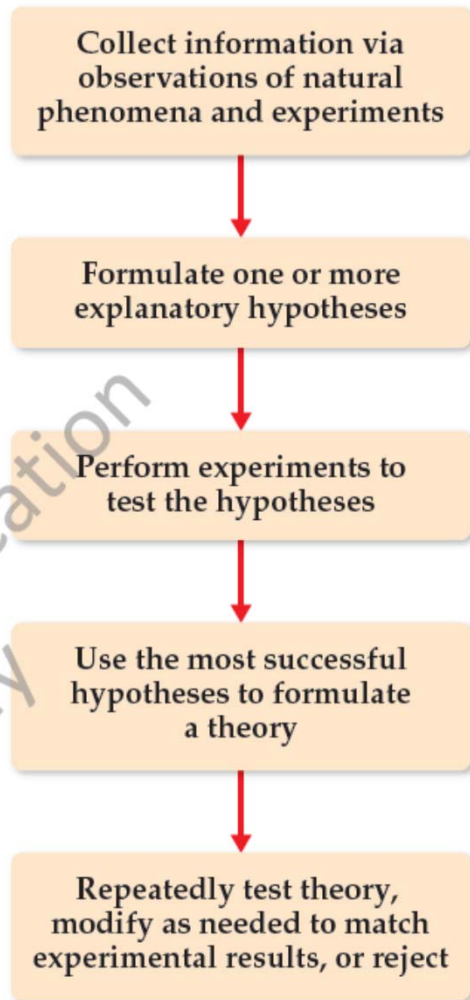


Chromatography



The differing abilities of substances to adhere to the surfaces of solids can also be used to separate mixtures. This ability is the basis of chromatography

The scientific method



▲ Figure 1.16 The scientific method.

Key characteristics of the scientific method include observation, formulation of hypotheses, experimentation, and formulation of laws and theories.

A hypothesis is a tentative interpretation or explanation of the observations.

A Scientific Law (科學定律)

A brief statement that summarizes past observations and predicts future ones

- EX: “In a chemical reaction matter is neither created nor destroyed.” ----- Law of conservation of mass (質量守恆定律)

SI Units

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— Metric System Prefixes

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

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

^aThe 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); $1 \text{ J} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^2$ and $1 \text{ W} = 1 \text{ J/s}$.

^bGreek letter mu, pronounced “mew.”

Using SI Prefixes

- What is the name of the unit that equals (a) 10^{-9} gram, (b) 10^{-6} second, (c) 10^{-3} meter?

Quiz

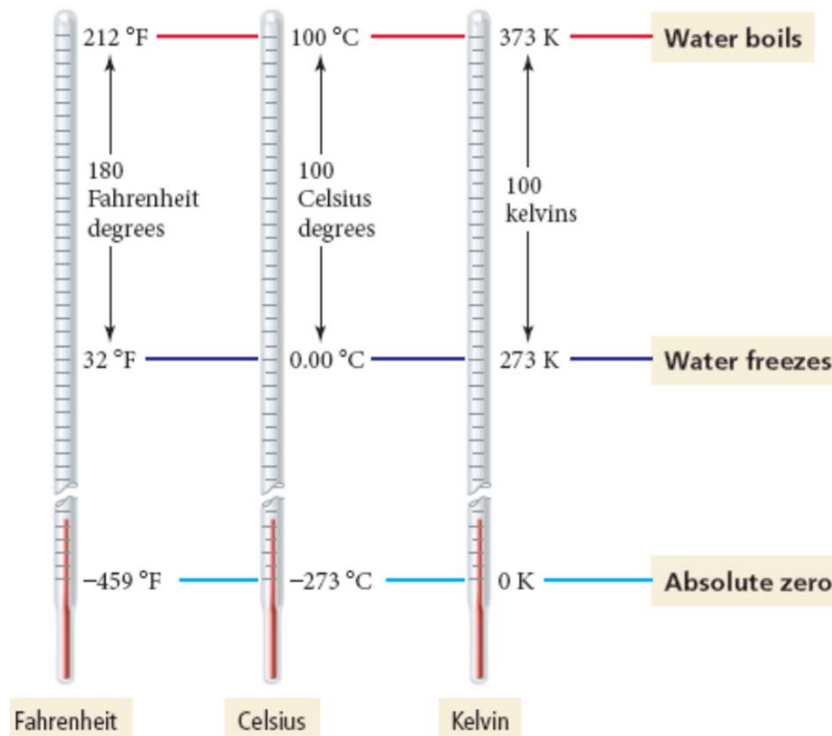
- One edge of a cube is measured and found to be 13 cm. The volume of the cube in m^3 is _____

Temperature

- The Kelvin (K) is the SI unit of temperature.
- The temperature is a measure of the average amount of kinetic energy of the atoms or molecules that compose the matter.
- Temperature also determines the direction of thermal energy transfer, or what we commonly call heat.
- Thermal energy transfers from hot to cold objects.

Kelvin scale

- Kelvin scale (absolute scale) assigns 0 K (absolute zero) to the coldest temperature possible.
- Absolute zero ($-273\text{ }^{\circ}\text{C}$ or $-459\text{ }^{\circ}\text{F}$) is the temperature at which molecular motion virtually stops. Lower temperatures do not exist.



Temperature

- The Fahrenheit degree (°F) is five-ninths the size of a Celsius degree.
- The Celsius degree (°C) and the Kelvin degree (K) are the same size.

$$^{\circ}\text{C} = \frac{(^{\circ}\text{F} - 32)}{1.8}$$

$$\text{K} = ^{\circ}\text{C} + 273.15$$

Converting between Temperature Scales

- A weather forecaster predicts the temperature will reach 31°C . What is this temperature (a) in K, (b) in $^{\circ}\text{F}$?

SOLUTION

(a) Using Equation 1.1, we have $K = 31 + 273 = 304\text{ K}$.

(b) Using Equation 1.2, we have

$$^{\circ}\text{F} = \frac{9}{5}(31) + 32 = 56 + 32 = 88^{\circ}\text{F}.$$

Derived Units

- A derived unit is a combination of other units.

EX: the SI unit for speed is meters per second (m/s), a derived unit.

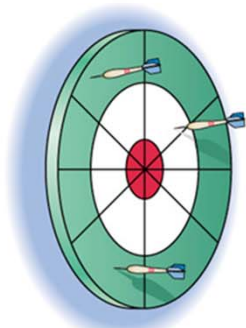
EX: Density has units that are derived from the units for mass and volume. (g/mL or g/cm³)

exact numbers & inexact numbers

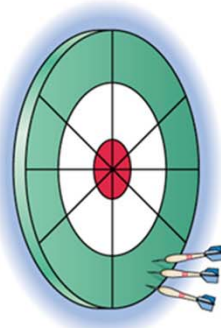
- Two kinds of numbers are encountered in scientific work: exact numbers (those whose values are known exactly) and inexact numbers (those whose values have some uncertainty).
 - Exact numbers : there are 12 eggs in 1 dozen.
 - Inexact (or measured) numbers : The balance measures to ± 0.01 g.

Accuracy versus Precision

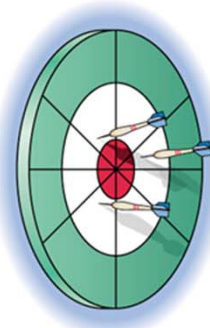
- Accuracy (準確度) refers to how close the measured value is to the actual value.
- Precision (精密度) refers to how close a series of measurements are to one another or how reproducible they are.



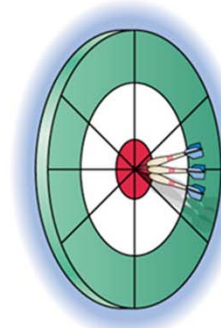
(a) Low accuracy
Low precision



(b) Low accuracy
High precision



(c) High accuracy
Low precision



(d) High accuracy
High precision

Copyright © 2004 Pearson Prentice Hall, Inc.

The Reliability of a Measurement

Scientific measurements are reported so that every digit is certain except the last, which is estimated.

EX:

5.213



certain estimated

The first three digits are certain; the last digit is estimated.

Significant Figures (有效數字)

- Significant figures deal with writing numbers to reflect precision (精密度).
- The precision of a measurement depends on the instrument used to make the measurement.
- The preservation of this precision during calculations can be accomplished by using significant figures.

Significant Figures Rules

Significant Figure Rules

1. All nonzero digits are significant.
2. Interior zeroes (zeroes between two nonzero digits) are significant.
3. Leading zeroes (zeroes to the left of the first nonzero digit) are not significant. They only serve to locate the decimal point.

Examples

28.03

0.0540

408

7.0301

0.0032

0.00006

not significant

Significant Figures Rules

4. Trailing zeroes (zeroes at the end of a number) are categorized as follows:

- Trailing zeroes after a decimal point are always significant.
- Trailing zeroes before a decimal point (and after a nonzero number) are always significant.
- Trailing zeroes before an *implied* decimal point are ambiguous and should be avoided by using scientific notation.
- Some textbooks put a decimal point after one or more trailing zeroes if the zeroes are to be considered significant. We avoid that practice in this book, but you should be aware of it.

45.000

140.00

1200

1.2×10^3

1.20×10^3

1.200×10^3

1200.

3.5600

2500.55

ambiguous

2 significant figures

3 significant figures

4 significant figures

4 significant figures
(common in some textbooks)

Exercise

- How many significant figures are in each number?

(a) 0.04450 m

(c) 10 dm = 1 m

(e) 0.00002 mm

(b) 5.0003 km

(d) 1.000×10^5 s

(f) 10,000 m

Quiz:

- How many significant figures are in each number?

A) 0.00002510

B) 0.02500001

C) 250000001

D) 2.501×10^{-7}

E) 2.5100000

Significant Figures in Calculations

- Multiplication and Division Rule:

In multiplication or division, the result carries the same number of significant figures as the factor with the fewest significant figures.

$$\begin{array}{ccccccc} 1.052 & \times & 12.504 & \times & 0.53 & = & 6.7208 = 6.7 \\ (4 \text{ sig. figures}) & & (5 \text{ sig. figures}) & & (2 \text{ sig. figures}) & & (2 \text{ sig. figures}) \end{array}$$

$$\begin{array}{ccccccc} 2.0035 & \div & 3.20 & = & 0.626094 = 0.626 \\ (5 \text{ sig. figures}) & & (3 \text{ sig. figures}) & & (3 \text{ sig. figures}) \end{array}$$

Exercise 1.8

- The width, length, and height of a small box are 15.5, 27.3, and 5.4 cm, respectively. Calculate the volume of the box, using the correct number of significant figures in your answer.

$$\begin{aligned}\text{Volume} &= \text{width} \times \text{length} \times \text{height} \\ &= (15.5 \text{ cm})(27.3 \text{ cm})(5.4 \text{ cm}) \\ &= 2285.01 \text{ cm}^3 \Rightarrow 2.3 \times 10^3 \text{ cm}^3\end{aligned}$$

Quiz

- 12.00000×0.9893
- 13.00335×0.0107
- $(2.0560)(0.9391) / 12.006 = \underline{\hspace{2cm}}$

Significant Figures in Calculations

- Addition and Subtraction Rule:

In addition or subtraction the result carries the same number of decimal places as the quantity with the fewest decimal places.

$$\begin{array}{r} 2.345 \\ 0.07 \\ 2.9975 \\ \hline 5.4125 \end{array} = 5.41$$

$$\begin{array}{r} 5.9 \\ - 0.221 \\ \hline 5.679 \end{array} = 5.7$$

Quiz

- The correct result (indicating the proper number of significant figures) of the following addition is _____.

$$12+1.2+0.12+0.012=?$$

Rounding in Multistep Calculations

- To avoid rounding errors in multistep calculations round only the final answer.
- Do not round intermediate steps. If you write down intermediate answers, keep track of significant figures by underlining the least significant digit.

$$\begin{aligned} &6.78 \times 5.903 \times (5.489 - 5.01) \\ &= 6.78 \times 5.903 \times 0.479 \\ &= 19.1707 \\ &= 19 \end{aligned}$$


underline least
significant digit

Exercise

(c) $4.562 \times 3.99870 \div (452.6755 - 452.33)$

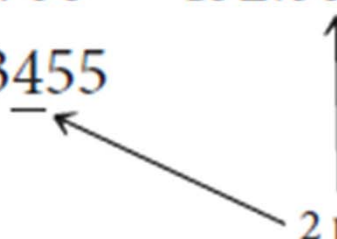
$$4.562 \times 3.99870 \div (452.6755 - 452.33)$$

$$= 4.562 \times 3.99870 \div 0.3455$$

$$= 52.79904$$

$$= 53$$

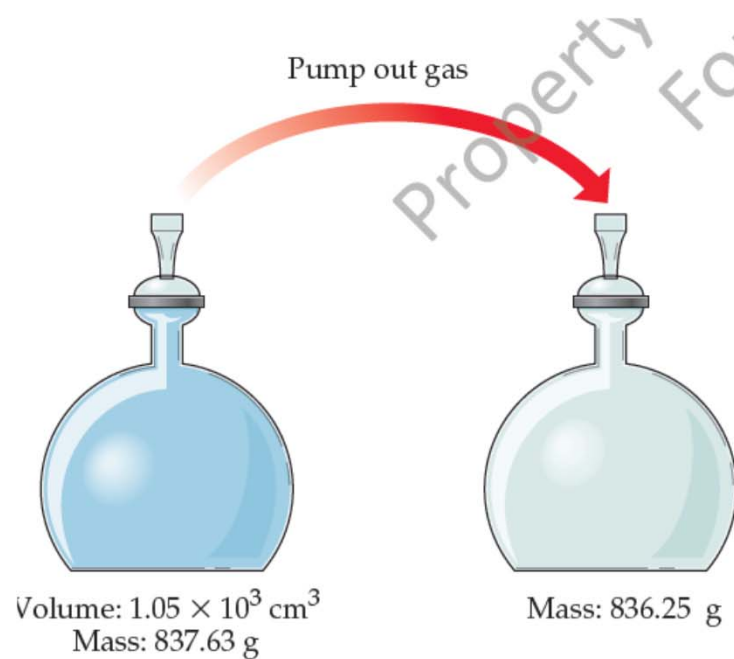
2 places of the decimal



Quiz

$$\frac{(10.07 + 7.395)}{2.5}$$

- A vessel containing a gas at 25 °C is weighed, emptied, and then reweighed as depicted in Figure 1.24. From the data provided, calculate the density of the gas at 25 °C



$$(837.63 - 836.25) \text{ g} = 1.38 \text{ g}$$

$$\text{Density} = \frac{\text{mass}}{\text{volume}} = \frac{1.38 \text{ g}}{1.05 \times 10^3 \text{ cm}^3}$$
$$= 1.31 \times 10^{-3} \text{ g/cm}^3 = 0.00131 \text{ g/cm}^3$$

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).
- We can set up a ratio of comparison for the equality either 1 in./2.54 cm or 2.54 cm/1 in.
- We use the ratio which allows us to change units (puts the units we have in the denominator to cancel).

Given:

m

Use
 $\frac{1 \text{ cm}}{10^{-2} \text{ m}}$

cm

Use
 $\frac{1 \text{ in.}}{2.54 \text{ cm}}$

Find:

in.