化学

Introduction

Chapter 1

目錄

Essential Concepts

The Study of Chemistry Chemistry is the study of the properties of matter and the changes it undergoes. Elements and compounds are substances that take part in chemical transformation.

Physical and Chemical Properties To characterize a substance, we need to know its physical properties, which can be observed without changing its identity. Chemical properties, however, can only be demonstrated by chemical changes.

Measurements and Units Chemistry is a quantitative science and requires measurements. The measured quantities (for example, mass, volume, density, and temperature) usually have units associated with them. The units used in chemistry are based on the international system (SI) of units.

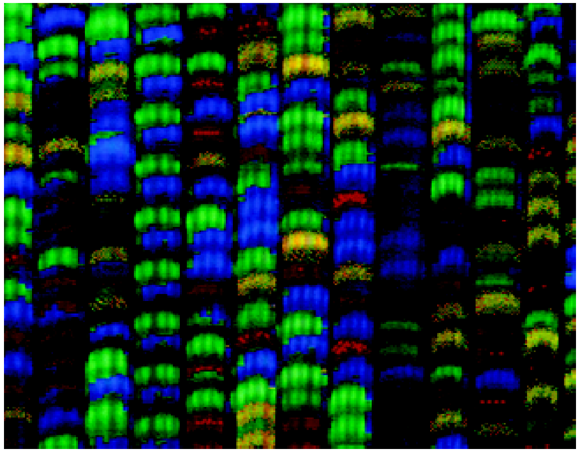
Essential Concepts (cont'd)

Handling Numbers Scientific notation is used to express large and small numbers, and each number in a measurement must indicate the meaningful digits, called significant figures.

Doing Chemical Calculations A simple and effective way to perform chemical calculations is dimensional analysis. In this procedure, an equation is set up in such a way that all the units cancel except the ones for the final answer.

Chemistry: A Science for the 21st Century

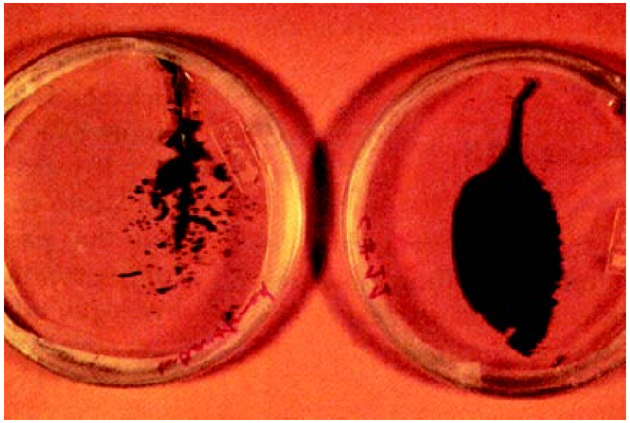
- Health and Medicine
  - Sanitation systems
  - Surgery with anesthesia
  - Vaccines and antibiotics
  - Gene therapy



- Energy and the Environment
  - Fossil fuels
  - Solar energy
  - Nuclear energy

Chemistry: A Science for the 21st Century

- Materials and Technology
  - Polymers, ceramics, liquid crystals
  - Room-temperature superconductors?
  - Molecular computing?

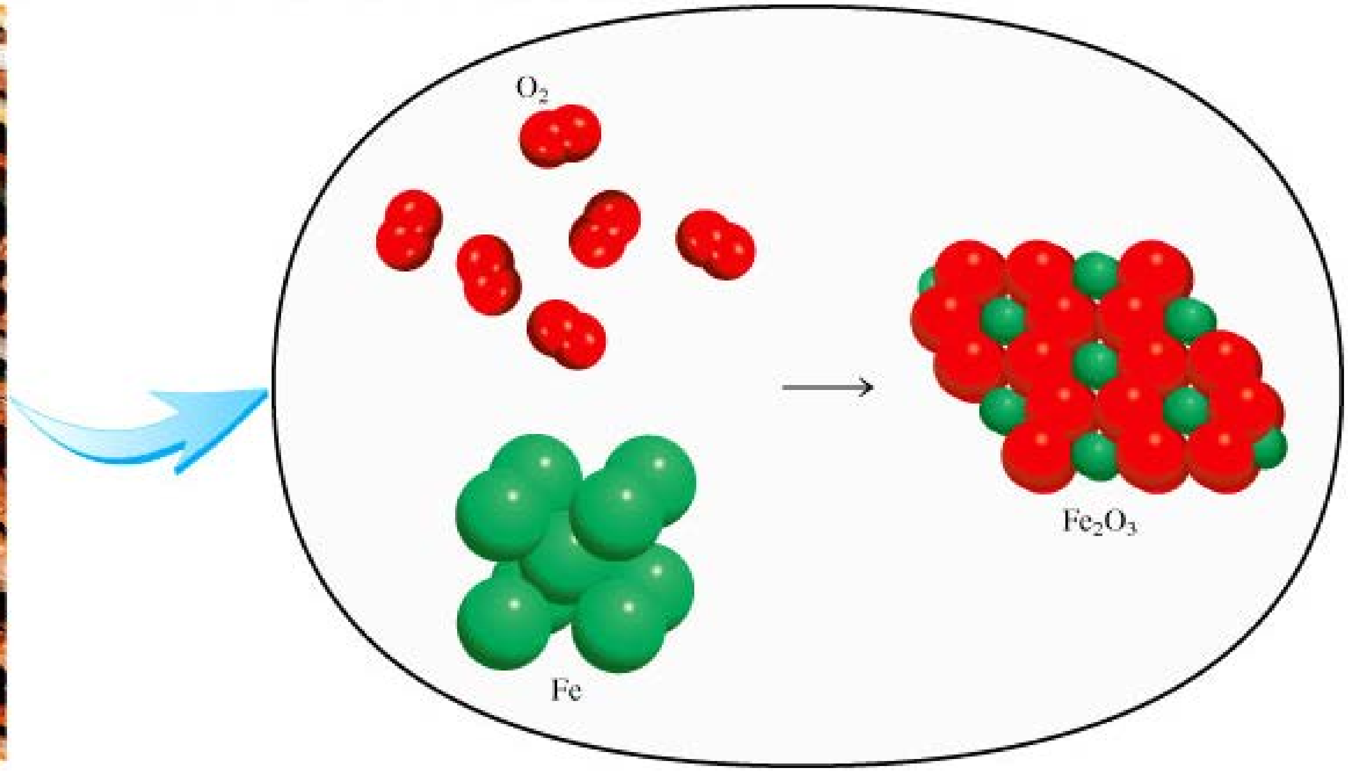


- Food and Agriculture
  - Genetically modified crops
  - “Natural” pesticides
  - Specialized fertilizers

1.1 The Study of Chemistry

Macroscopic

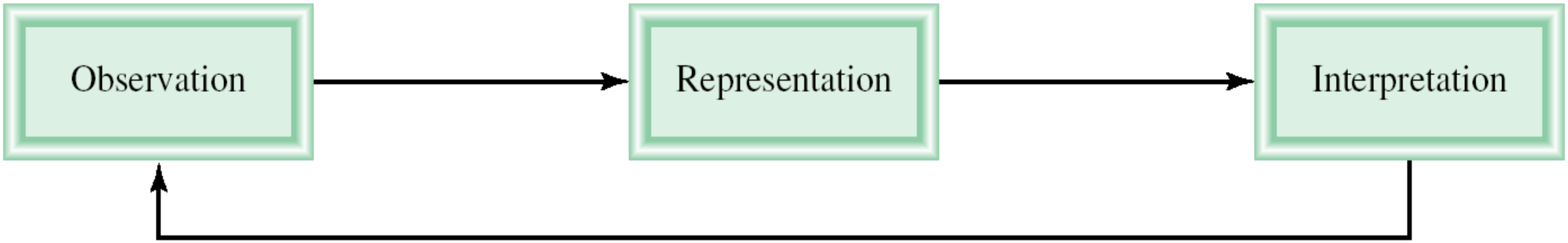
Microscopic



化學是一門用來瞭解物質的本性，
以及物質之間互相作用原理的科學

1.2 The Scientific Method

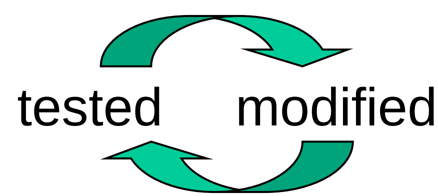
The ***scientific method*** is a systematic approach to research



A ***hypothesis*** is a tentative explanation for a set of observations

Observation: 看巨觀世界的事件；原子和分子構成微觀世界
Representation: 以符號和化學方程式來描述實驗或事件
Interpretation: 從原子和分子觀點來解釋所觀察現象

The scientific method includes: a) defining the problem; b) make qualitative and quantitative observations; c) recording the data; d) interpreting the data into a hypothesis; e) testing the hypothesis with more observations until a theory is developed; and f) examining the theory over time until a law is accepted. （例如：盤尼西林--青黴素--的發現）

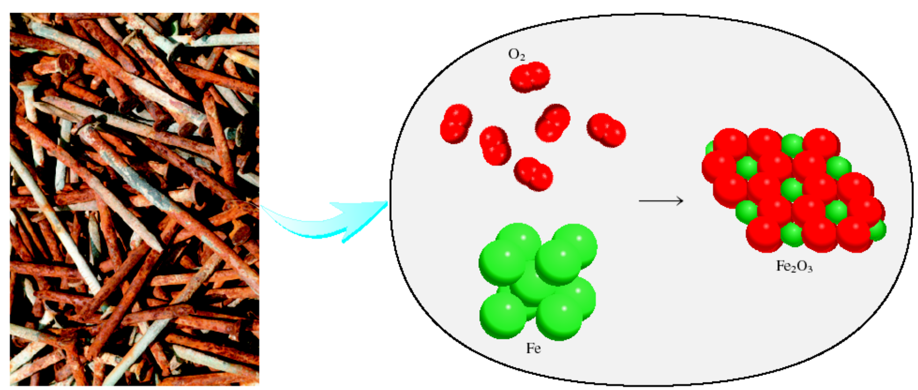


A ***law*** (定理、定律) is a concise statement of a relationship between phenomena that is always the same under the same conditions.

Force = mass x acceleration

A ***theory*** (理論) is a unifying principle that explains a body of facts and/or those laws that are based on them. 以原子理論來解釋定比定律、倍比定律或gas law。

Atomic Theory



1.3 Classifications of Matter

Chemistry is the study of matter and the changes it undergoes.

H_2O

Matter is anything that occupies space and has mass.

Ice, water, steam

A ***substance*** is a form of matter that has a definite composition and distinct properties.

liquid nitrogen

gold ingots 錠

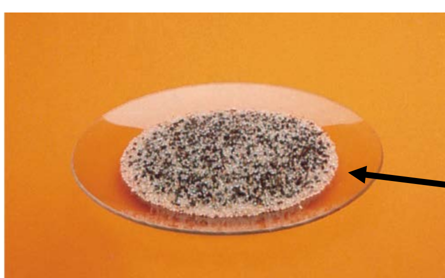
silicon crystals

A ***mixture*** is a combination of two or more substances in which the substances retain their distinct identities.

1. ***Homogeneous mixture*** – composition of the mixture is the same throughout.

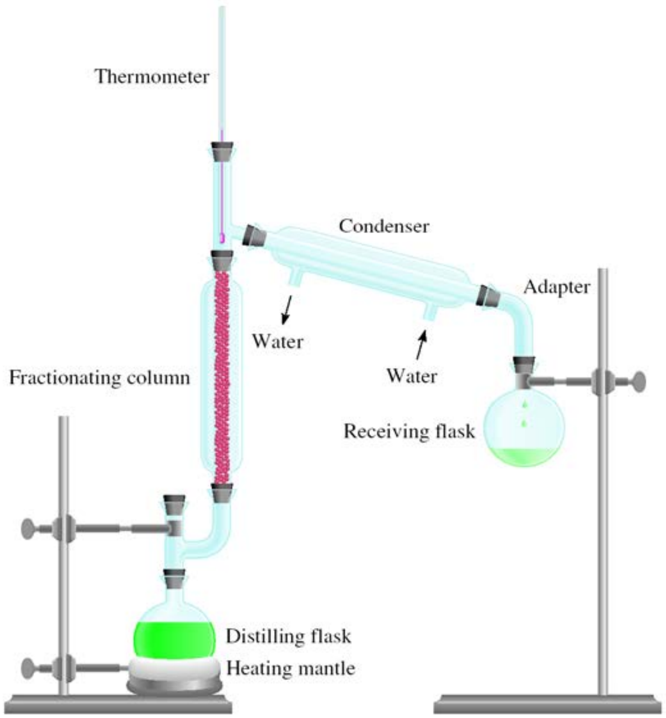
soft drink, milk, solder

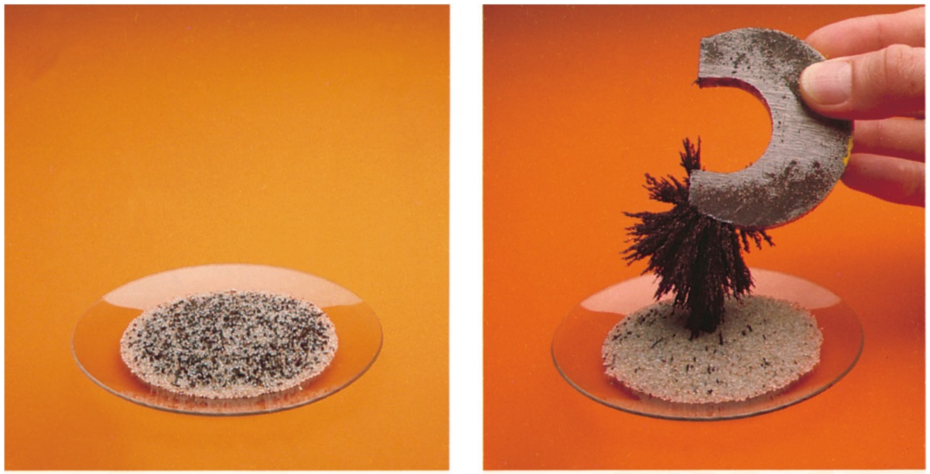
2. ***Heterogeneous mixture*** – composition is not uniform throughout.



cement,
iron filings in sand

__Physical means__ can be used to separate a mixture into its pure components (組成分).





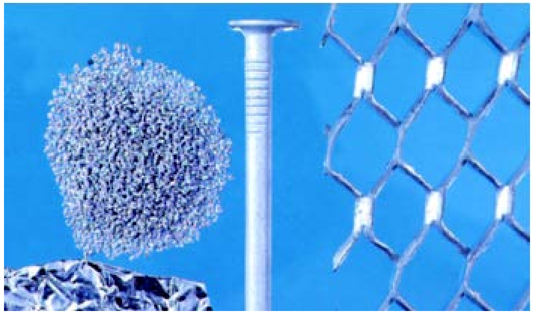
magnet

distillation

An ***element*** is a substance that cannot be separated into simpler substances by ***chemical means***.

- 117 elements have been identified
  - 82 stable elements occur naturally on Earth

    gold, iron, lead, oxygen, carbon, sulfur



  - 35 elements have been created by scientists

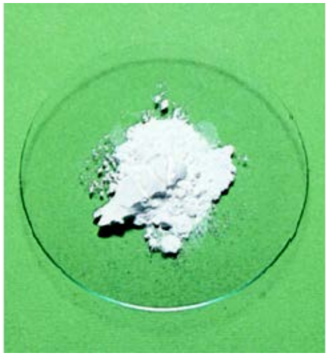
    Technetium ($_{43}Tc$), americium ($_{95}Am$), seaborgium ($_{106}Sg$)

TABLE 1.1 Some Common Elements and Their Symbols

Name	Symbol	Name	Symbol	Name	Symbol
Aluminum	Al	Fluorine	F	Oxygen	O
Arsenic	As	Gold	Au	Phosphorus	P
Barium	Ba	Hydrogen	H	Platinum	Pt
Bismuth	Bi	Iodine	I	Potassium	K
Bromine	Br	Iron	Fe	Silicon	Si
Calcium	Ca	Lead	Pb	Silver	Ag
Carbon	C	Magnesium	Mg	Sodium	Na
Chlorine	Cl	Manganese	Mn	Sulfur	S
Chromium	Cr	Mercury	Hg	Tin	Sn
Cobalt	Co	Nickel	Ni	Tungsten	W
Copper	Cu	Nitrogen	N	Zinc	Zn

A ***compound*** is a substance composed of atoms of two or more elements chemically united in fixed proportions.

Compounds can only be separated into their pure components (elements) by ***chemical*** means.

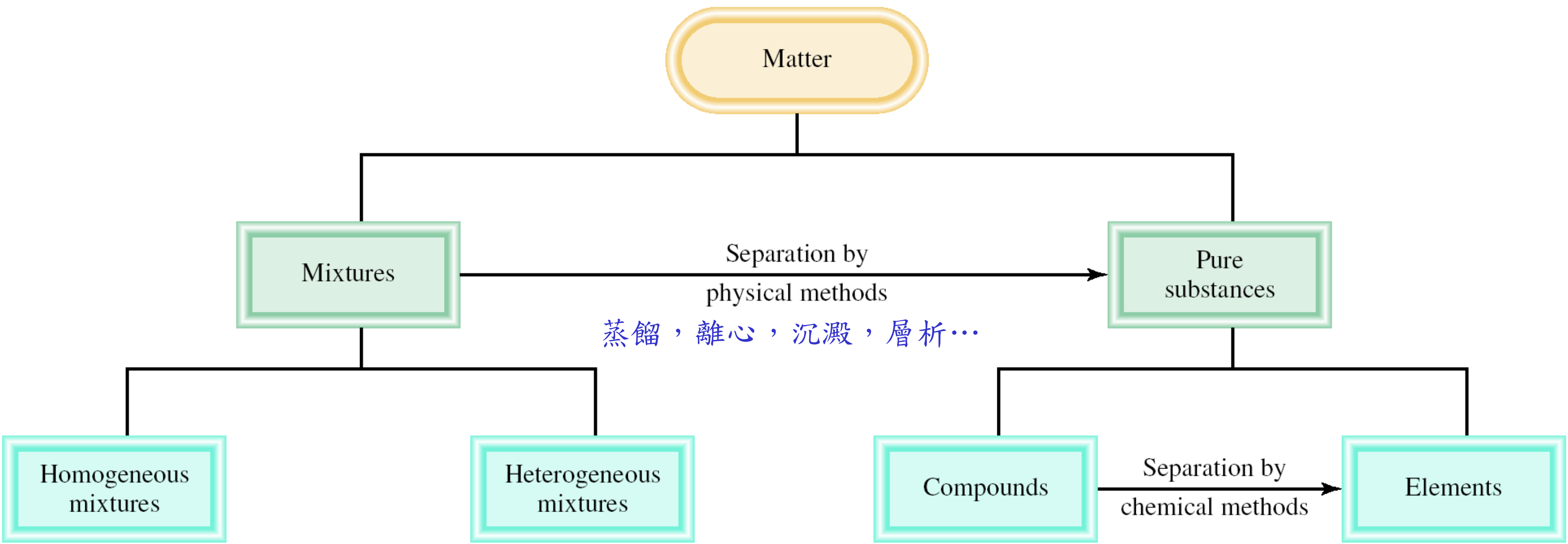


lithium fluoride

Quartz
(SiO_2)

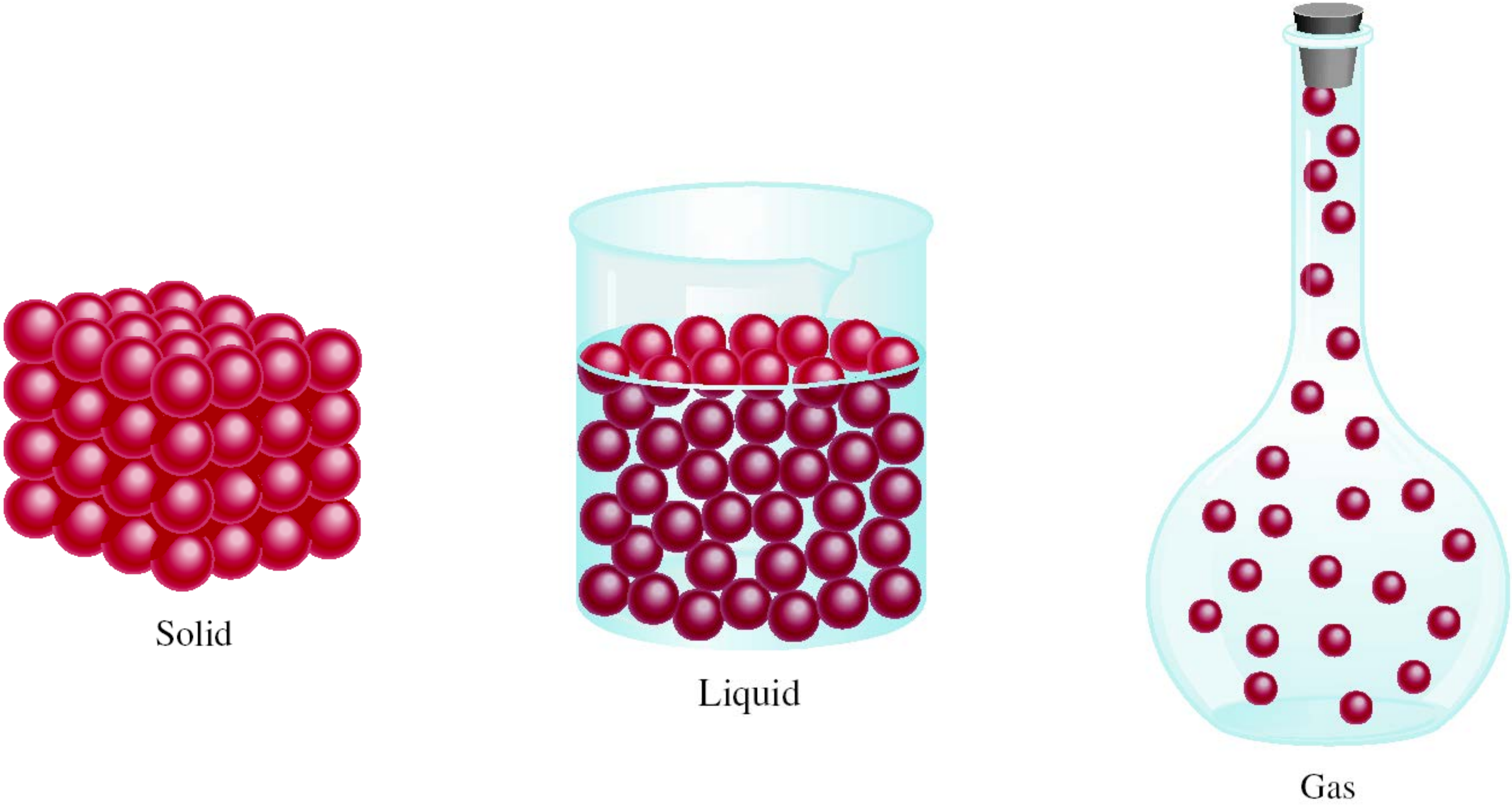
dry ice
(carbon dioxide)

Classifications of Matter

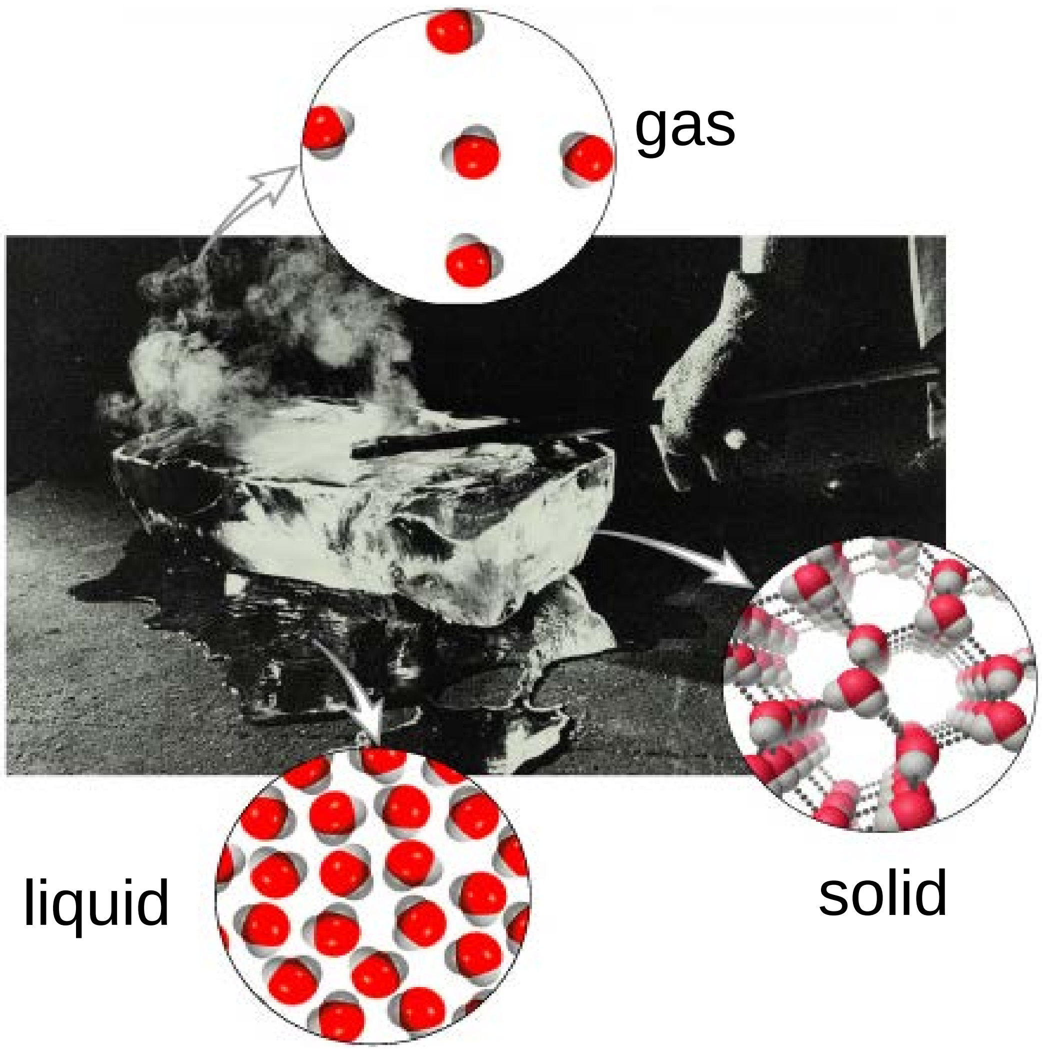


1.4 Physical and Chemical Properties of Matter

A Comparison: The Three States of Matter



The three states of matter:
Effect of a hot poker (火鉗) on a block of ice.



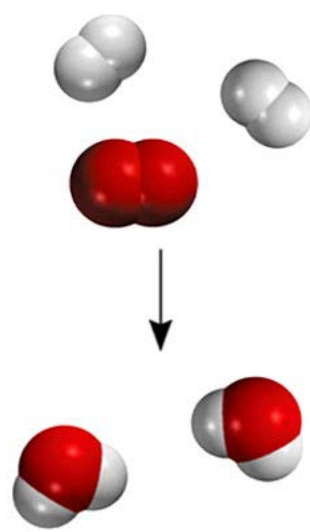
Types of Changes

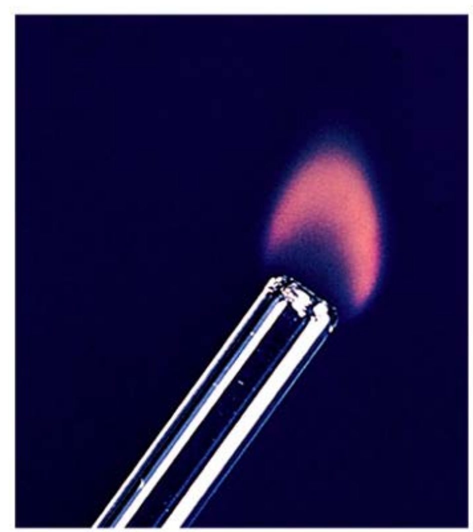
A ***physical change*** does not alter the composition or identity of a substance.

ice melts; sugar dissolves in water

A ***chemical change*** alters the composition or identity of the substance(s) involved.

hydrogen burns in air to form water

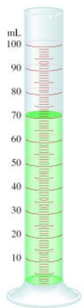




Extensive and Intensive Properties

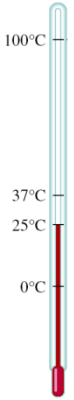
An ***extensive property*** of a material depends upon how much matter is being considered.

- mass
- length
- volume



An ***intensive property*** of a material does not depend upon how much matter is being considered.

- density
- temperature
- color



1.5 Measurement

Matter - anything that occupies space and has ***mass***.

H_2O

mass – measure of the quantity of matter

SI unit of mass is the ***kilogram*** (kg)

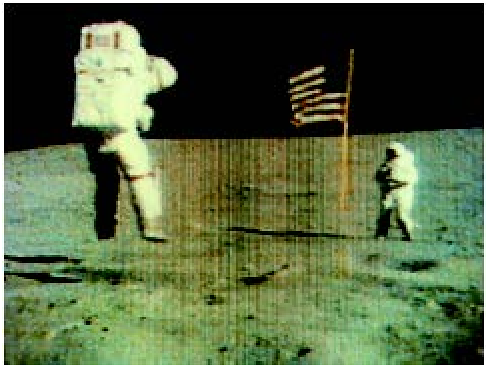
1 kg = 1000 g = 1 x 10^3 g

weight – force that gravity exerts on an object

weight = *c* x mass

on earth, *c* = 1.0

on moon, *c* ~ 0.1



A 1 kg bar will weigh

1 kg on earth

0.1 kg on moon

International System of Units (SI)

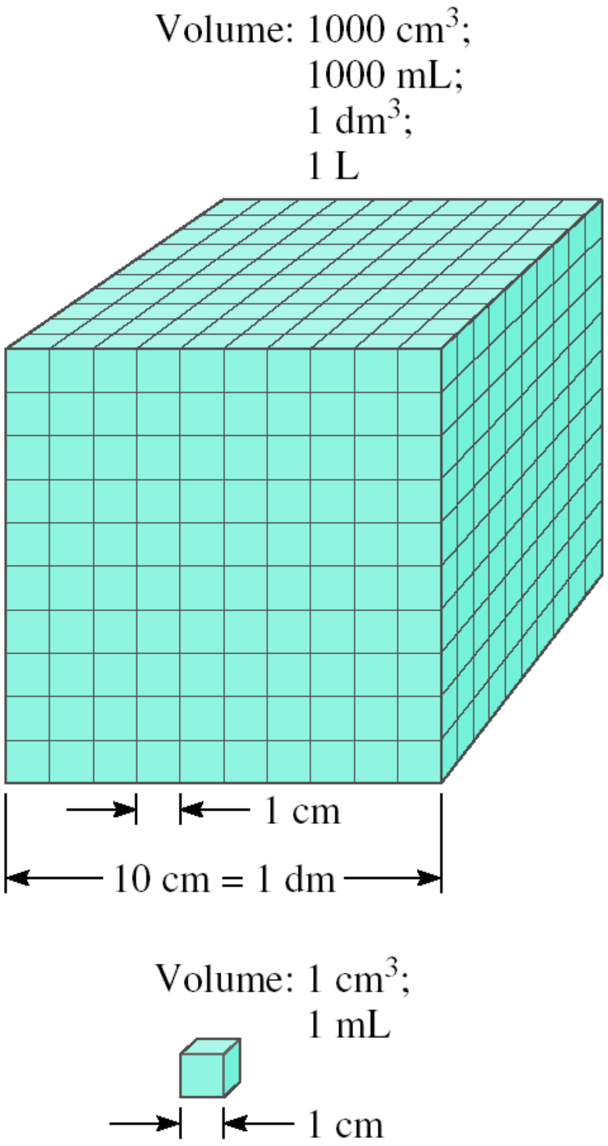
TABLE 1.2 SI Base Units

Base Quantity	Name of Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Electrical current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

TABLE 1.3 Prefixes Used with SI Units

Prefix	Symbol	Meaning	Example
tera-	T	1,000,000,000,000, or 10^{12}	1 terameter (Tm) = 1×10^{12} m
giga-	G	1,000,000,000, or 10^{9}	1 gigameter (Gm) = 1×10^{9} m
mega-	M	1,000,000, or 10^{6}	1 megameter (Mm) = 1×10^{6} m
kilo-	k	1,000, or 10^{3}	1 kilometer (km) = 1×10^{3} m
deci-	d	1/10, or 10^{-1}	1 decimeter (dm) = 0.1 m
centi-	c	1/100, or 10^{-2}	1 centimeter (cm) = 0.01 m
milli-	m	1/1,000, or 10^{-3}	1 millimeter (mm) = 0.001 m
micro-	μ	1/1,000,000, or 10^{-6}	1 micrometer (μm) = 1×10^{-6} m
nano-	n	1/1,000,000,000, or 10^{-9}	1 nanometer (nm) = 1×10^{-9} m
pico-	p	1/1,000,000,000,000, or 10^{-12}	1 picometer (pm) = 1×10^{-12} m

Volume – SI derived unit for volume is cubic meter (m^3)



$$1\ cm^3 = (1 \times 10^{-2}\ m)^3 = 1 \times 10^{-6}\ m^3$$

$$1\ dm^3 = (1 \times 10^{-1}\ m)^3 = 1 \times 10^{-3}\ m^3$$

$$1\ L = 1000\ mL = 1000\ cm^3 = 1\ dm^3$$

$$\boxed{1\ mL = 1\ cm^3}$$

Density – SI derived unit for density is kg/m^3

$1\ g/cm^3 = 1\ g/mL = 1000\ kg/m^3$

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad d = \frac{m}{V}$$

A piece of platinum metal with a density of 21.5 g/cm^3 has a volume of 4.49 cm^3. What is its mass?

$$d = \frac{m}{V}$$

$$m = d \times V = 21.5\ g/\cancel{cm^3} \times 4.49\ \cancel{cm^3} = 96.5\ g$$

TABLE 1.4

Densities of Some Substances at 25°C

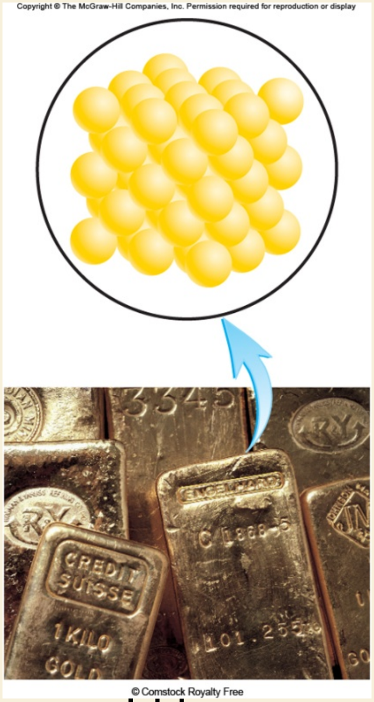
Substance	Density (g/cm^3)
Air*	0.001
Ethanol	0.79
Water	1.00
Mercury	13.6
Table salt	2.2
Iron	7.9
Gold	19.3
Osmium†	22.6

*Measured at 1 atmosphere.
†Osmium (Os) is the densest element known.

Example 1.1

Gold is a precious metal that is chemically unreactive. It is used mainly in jewelry, dentistry, and electronic devices.

A piece of gold ingot with a mass of 301 g has a volume of 15.6 cm^3. Calculate the density of gold.



gold ingots

Example 1.1

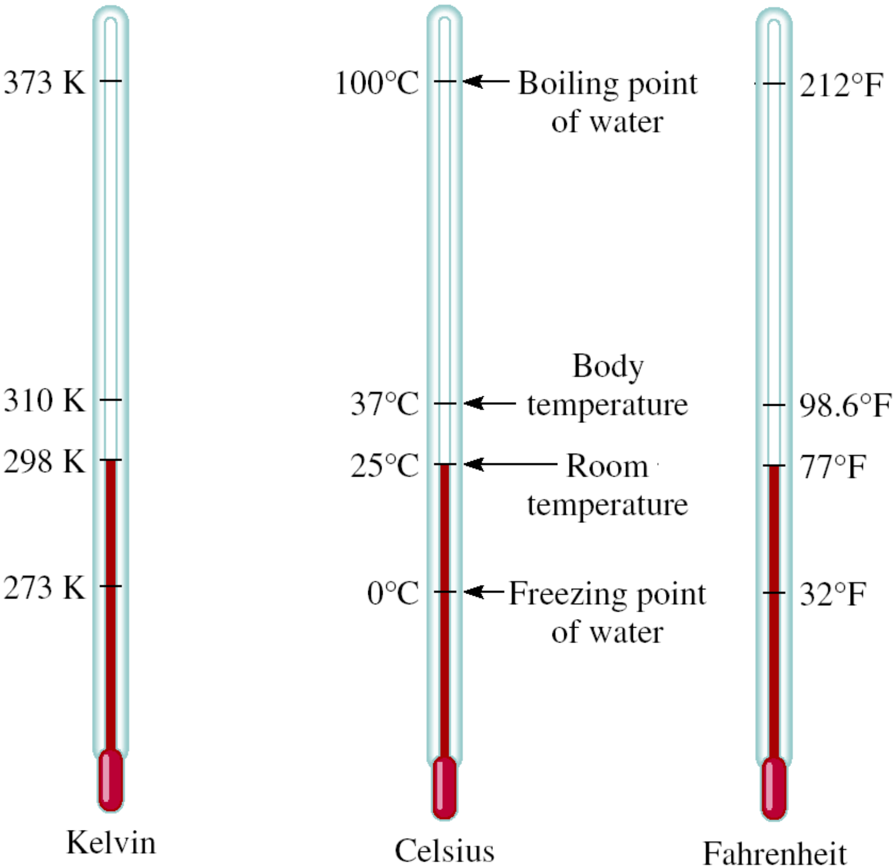
Solution We are given the mass and volume and asked to calculate the density. Therefore, from Equation (1.1), we write

$$d = \frac{m}{V}$$

$$= \frac{301\ \text{g}}{15.6\ \text{cm}^3}$$

$$= 19.3\ \text{g/cm}^3$$

A Comparison of Temperature Scales



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

$$273\ K = 0\ {}^{\circ}C$$

$$373\ K = 100\ {}^{\circ}C$$

$${}^{\circ}F = \frac{9}{5} \times {}^{\circ}C + 32$$

$$32\ {}^{0}F = 0\ {}^{\circ}C$$

$$212\ {}^{0}F = 100\ {}^{\circ}C$$

Example 1.2

(a) Solder is an alloy made of tin and lead that is used in electronic circuits. A certain solder has a melting point of 224°C. What is its melting point in degrees Fahrenheit?

(b) Helium has the lowest boiling point of all the elements at -452°F. Convert this temperature to degrees Celsius.

(c) Mercury, the only metal that exists as a liquid at room temperature, melts at -38.9°C. Convert its melting point to kelvins.

Example 1.2

Solution These three parts require that we carry out temperature conversions, so we need Equations (1.2), (1.3), and (1.4). Keep in mind that the lowest temperature on the Kelvin scale is zero (0 K); therefore, it can never be negative.

(a)This conversion is carried out by writing

$$\frac{9^\circ\text{F}}{5^\circ\text{C}} \times (224^\circ\text{C}) + 32^\circ\text{F} = 435^\circ\text{F}$$

(b)Here we have

$$(-452^\circ\text{F} - 32^\circ\text{F}) \times \frac{5^\circ\text{C}}{9^\circ\text{F}} = -269^\circ\text{C}$$

(c)The melting point of mercury in kelvins is given by

$$(-38.9^\circ\text{C} + 273.15^\circ\text{C}) \times \frac{1\ \text{K}}{1^\circ\text{C}} = 234.3\ \text{K}$$

1.6 Handling Numbers

Scientific Notation

The number of atoms in 12 g of carbon:

602,200,000,000,000,000,000,000

6.022×10^{23}

The mass of a single carbon atom in grams:

0.0000000000000000000000199

1.99×10^{-23}

$$\boxed{N \times 10^{n}}$$

N is a number between 1 and 10

n is a positive or negative integer

Scientific Notation

568.762

← move decimal left

$n > 0$

$568.762 = 5.68762 \times 10^{2}$

0.00000772

→ move decimal right

$n < 0$

$0.00000772 = 7.72 \times 10^{-6}$

Addition or Subtraction

1. Write each quantity with the same exponent *n*
2. Combine N_1 and N_2
3. The exponent, *n*, remains the same

$4.31 \times 10^{4} + 3.9 \times 10^{3} =$

$4.31 \times 10^{4} + 0.39 \times 10^{4} =$

4.70×10^{4}

Scientific Notation

Multiplication

1. Multiply N_1 and N_2
2. Add exponents n_1 and n_2

$$(4.0 \times 10^{-5}) \times (7.0 \times 10^{3}) =$$
$$(4.0 \times 7.0) \times (10^{-5+3}) =$$
$$28 \times 10^{-2} =$$
$$2.8 \times 10^{-1}$$

Division

1. Divide N_1 and N_2
2. Subtract exponents n_1 and n_2

$$8.5 \times 10^{4} \div 5.0 \times 10^{9} =$$
$$(8.5 \div 5.0) \times 10^{4-9} =$$
$$1.7 \times 10^{-5}$$

Significant Figures

- Any digit that is not zero is significant

  1.234 kg   4 significant figures

- Zeros between nonzero digits are significant

  606 m   3 significant figures

- Zeros to the left of the first nonzero digit are **not** significant

  0.08 L   1 significant figure

- If a number is greater than 1, then all zeros to the right of the decimal point are significant

  2.0 mg   2 significant figures

- If a number is less than 1, then only the zeros that are at the end and in the middle of the number are significant

  0.00420 g   3 significant figures

Example 1.3

Determine the number of significant figures in the following measurements:

(a)394 cm

(b)5.03 g

(c)0.714 m

(d)0.052 kg

(e)2.720×10^{22} atoms

(f)3000 mL

Example 1.3

Solution

(a) 394 cm -- Three, because each digit is a nonzero digit.

(b) 5.03 g -- Three, because zeros between nonzero digits are significant.

(c) 0.714 m -- Three, because zeros to the left of the first nonzero digit do not count as significant figures.

(d) 0.052 kg -- Two. Same reason as in (c).

(e) 2.720×10^{22} atoms -- Four, because the number is greater than one so all the zeros written to the right of the decimal point count as significant figures.

Example 1.3

(f)3000 mL -- This is an ambiguous case. The number of significant figures may be four (3.000×10^3), three (3.00×10^3), two (3.0×10^3), or one (3×10^3).

This example illustrates why scientific notation must be used to show the proper number of significant figures.

How many significant figures are in each of the following measurements?

24 mL	2 significant figures
3001 g	4 significant figures
0.0320 m^3	3 significant figures
6.4 x 10^4 molecules	2 significant figures
560 kg	2 significant figures

Significant Figures

Addition or Subtraction （取最少有效小數位）

The answer cannot have more **digits to the right of the decimal point** than any of the original numbers.

89.332
+1.1 ⟵ one significant figure after decimal point
90.432 ⟵ round off to 90.4

3.70 ⟵ two significant figures after decimal point
-2.9133
0.7867 ⟵ round off to 0.79

Significant Figures

Multiplication or Division （取最少有效數字）

The number of significant figures in the result is set by the original number that has the ***smallest* number of significant figures**.

$$4.51 \times 3.6666 = 16.536366 = 16.5$$

3 sig figs　　　round to 3 sig figs

$$6.8 \div 112.04 = 0.0606926 = 0.061$$

2 sig figs　　　round to 2 sig figs

$$\frac{(15.49+9)(24)(3.9506)}{5.7623} = \frac{(24)(3.9506)}{5.7623} = 16$$

Significant Figures

Exact Numbers

Numbers from definitions or numbers of objects are considered to have an infinite number of significant figures

The average of three measured lengths: 6.64, 6.68 and 6.70?

$$\frac{6.64 + 6.68 + 6.70}{3} = 6.67333 = 6.67 \cancel{= 7}$$

Because 3 is an ***exact number***

Example 1.4

Carry out the following arithmetic operations to the correct number of significant figures:

(a) 11,254.1 g + 0.1983 g

(b) 66.59 L − 3.113 L

(c) 8.16 m $\times$ 5.1355

(d) 0.0154 kg $\div$ 88.3 mL

(e) 2.64×10^3 cm + 3.27×10^2 cm

Example 1.4

Solution In addition and subtraction, the number of decimal places in the answer is determined by the number having the lowest number of decimal places. In multiplication and division, the significant number of the answer is determined by the number having the smallest number of significant figures.

(a)

$$\begin{array}{r} 11{,}254.1 \text{ g} \\ + \quad 0.1983 \text{ g} \\ \hline 11{,}254.2983 \text{ g} \end{array} \leftarrow \text{round off to } 11{,}254.3 \text{ g}$$

(b)

$$\begin{array}{r} 66.59 \text{ L} \\ -\ 3.113 \text{ L} \\ \hline 63.477 \text{ L} \end{array} \leftarrow \text{round off to } 63.48 \text{ L}$$

Example 1.4

(c) $8.16 \text{ m} \times 5.1355 = 41.90568 \text{ m} \longleftarrow$ round off to 41.9 m

(d) $\dfrac{0.0154 \text{ kg}}{88.3 \text{ mL}} = 0.000174405436 \text{ kg/mL} \leftarrow$ round off to

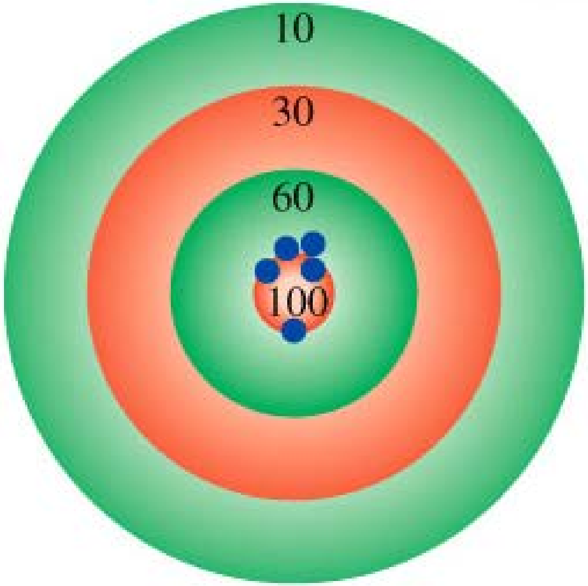
0.000174 kg/mL

or $1.74 \times 10^{-4} \text{ kg/mL}$

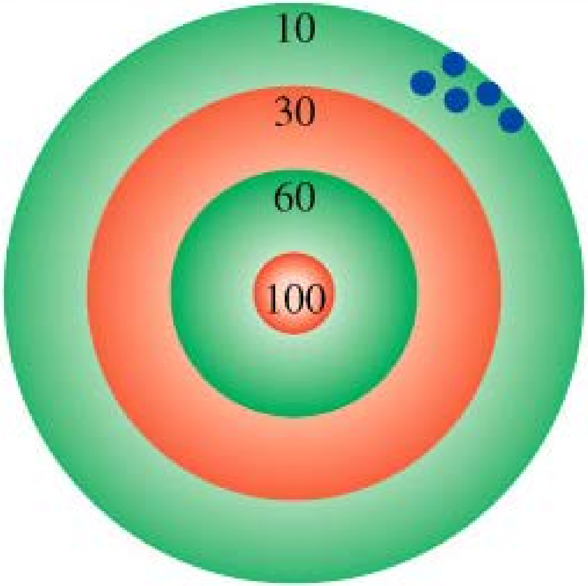
(e) First we change 3.27×10^2 cm to 0.327×10^3 cm and then carry out the addition $(2.64 \text{ cm} + 0.327 \text{ cm}) \times 10^3$. Following the procedure in (a), we find the answer is 2.97×10^3 cm.

Accuracy – how close a measurement is to the *true* value

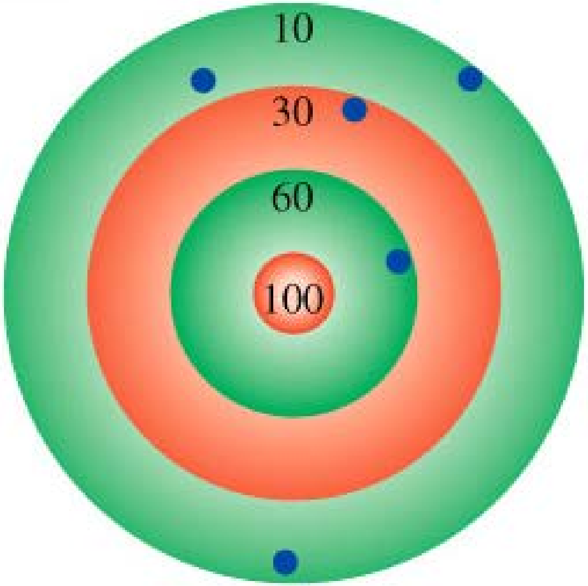
Precision – how close a set of measurements are to each other



accurate
&
precise



precise
but
not accurate



not accurate
&
not precise

1.7 Dimensional Analysis in Solving Problems

1. Determine which unit conversion factor(s) are needed
2. Carry units through calculation (帶著單位算)
3. If all units cancel except for the ***desired unit(s)***, then the problem was solved correctly.

given quantity x conversion factor = desired quantity

$$\cancel{\text{given unit}} \times \frac{\text{desired unit}}{\cancel{\text{given unit}}} = \text{desired unit}$$

Example 1.5

A person's average daily intake of glucose (a form of sugar) is 0.0833 pound (lb). What is this mass in milligrams (mg)?

(1 lb = 453.6 g.)

3個有效數字

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Example 1.5

Solution The sequence of conversions is

$$\text{pounds} \longrightarrow \text{grams} \longrightarrow \text{milligrams}$$

Using the following conversion factors

$$\frac{453.6\text{ g}}{1\text{ lb}} \quad \text{and} \quad \frac{1\text{ mg}}{1\times 10^{-3}\text{ g}}$$

we obtain the answer in one step:

$$?\text{ mg} = 0.0833\ \cancel{\text{lb}} \times \frac{453.6\ \cancel{\text{g}}}{1\ \cancel{\text{lb}}} \times \frac{1\text{ mg}}{1\times 10^{-3}\ \cancel{\text{g}}} = \underline{3.78}\times 10^{4}\text{ mg}$$

3個有效數字

Example 1.6

A cryogenic storage tank for liquid helium.

A liquid helium storage tank has a volume of 275 L. What is the volume in m^3?

Example 1.7

Liquid nitrogen is obtained from liquefied air and is used to prepare frozen goods and in low-temperature research.

The density of the liquid at its boiling point ($-196^{\circ}C$ or 77 K) is 0.808 g/cm^3. Convert the density to units of kg/m^3.

Ex. 甲液體密度1.2 g/cm^3，乙液體密度2.0 g/cm^3，混合後得密度1.8 g/cm^{3}的液體360 g ，求甲跟乙質量?

liquid nitrogen 1 kg 約30元

The speed of sound in air is about 343 m/s. What is this speed in miles per hour?

conversion units

meters to miles

seconds to hours

1 mi = 1609 m   1 min = 60 s   1 hour = 60 min

$$343 \frac{\cancel{m}}{\cancel{s}} \times \frac{1\ mi}{1609\ \cancel{m}} \times \frac{60\ \cancel{s}}{1\ \cancel{min}} \times \frac{60\ \cancel{min}}{1\ hour} = 767 \frac{mi}{hour}$$