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GENERAL CHEMISTRY I

Dr. Vu Thi Ngoc Minh

Office: C4-103

Email: minh.vuthingoc@hust.edu.vn

Office hour: by appointment

Textbook: Chemistry: The Central Science, By Theodore E. Brown

Expected Learning Outcomes

1. Understand the basic principles of general chemistry
2. Be able to explain basic, everyday chemical phenomena and apply your knowledge to solving real-world problems
3. Be able to explain why chemistry is essential and how it applies to everyday life

5 ways to fail this course

- Use communication devices in the exams
- Do not fully participate in the lab sections
- Take more than 3 absent days with or without the faculty's permission
- Fake lab data
- Plagiarize

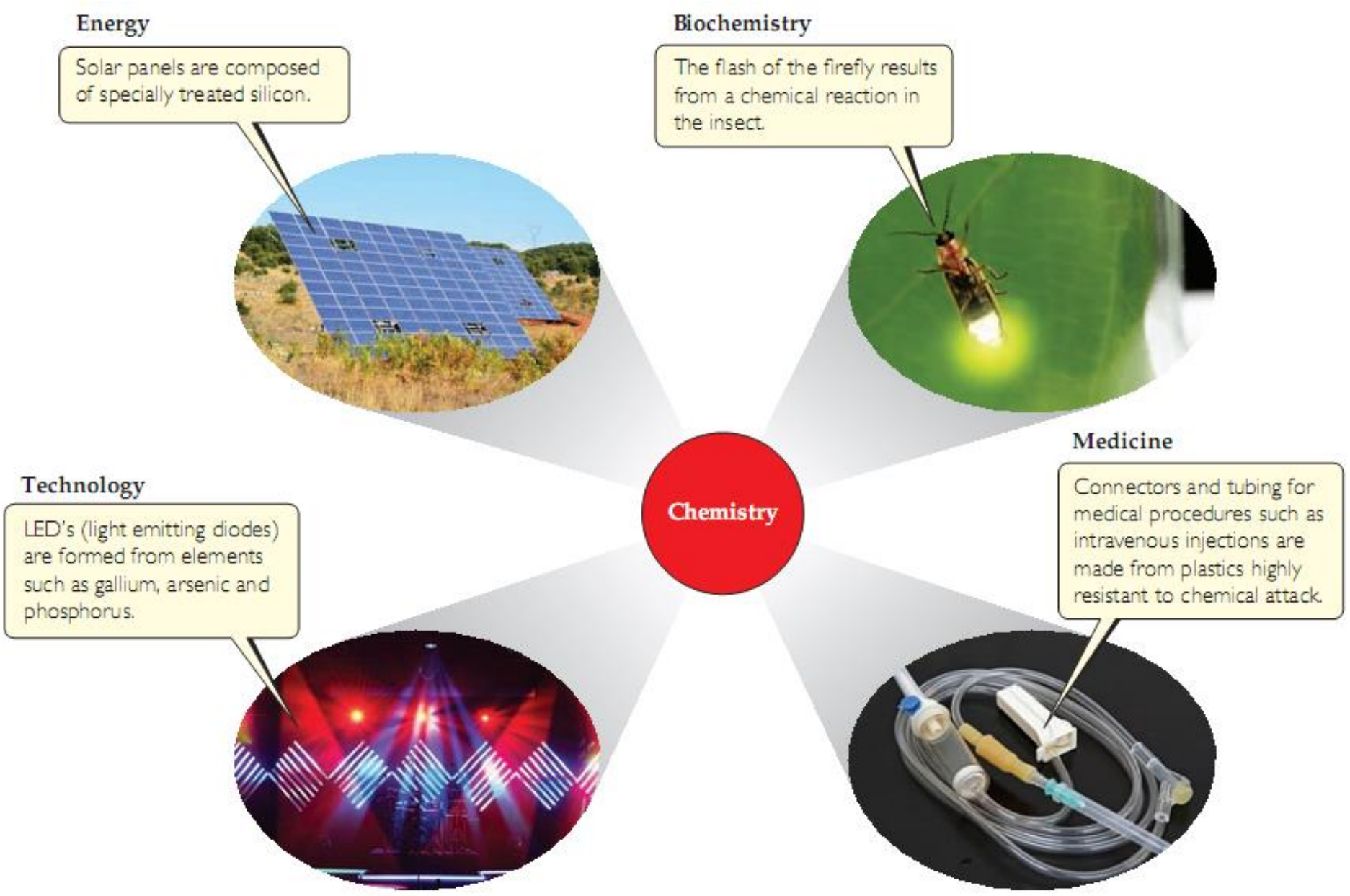
What’s your own definition of chemistry?

GENERAL CHEMISTRY I

Chapter 1
Introduction: Matter and Measurement

Contents

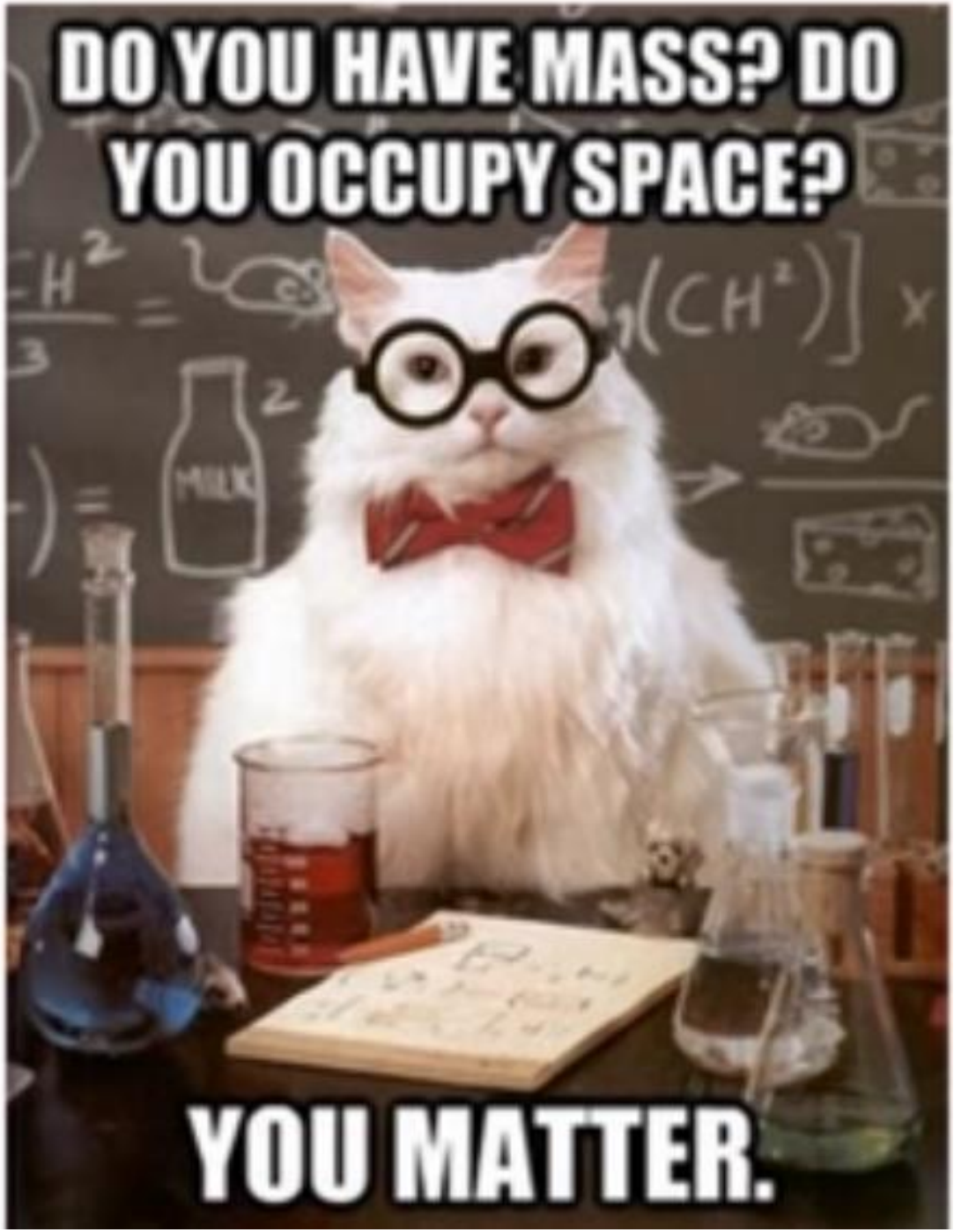
Chemistry is all around us



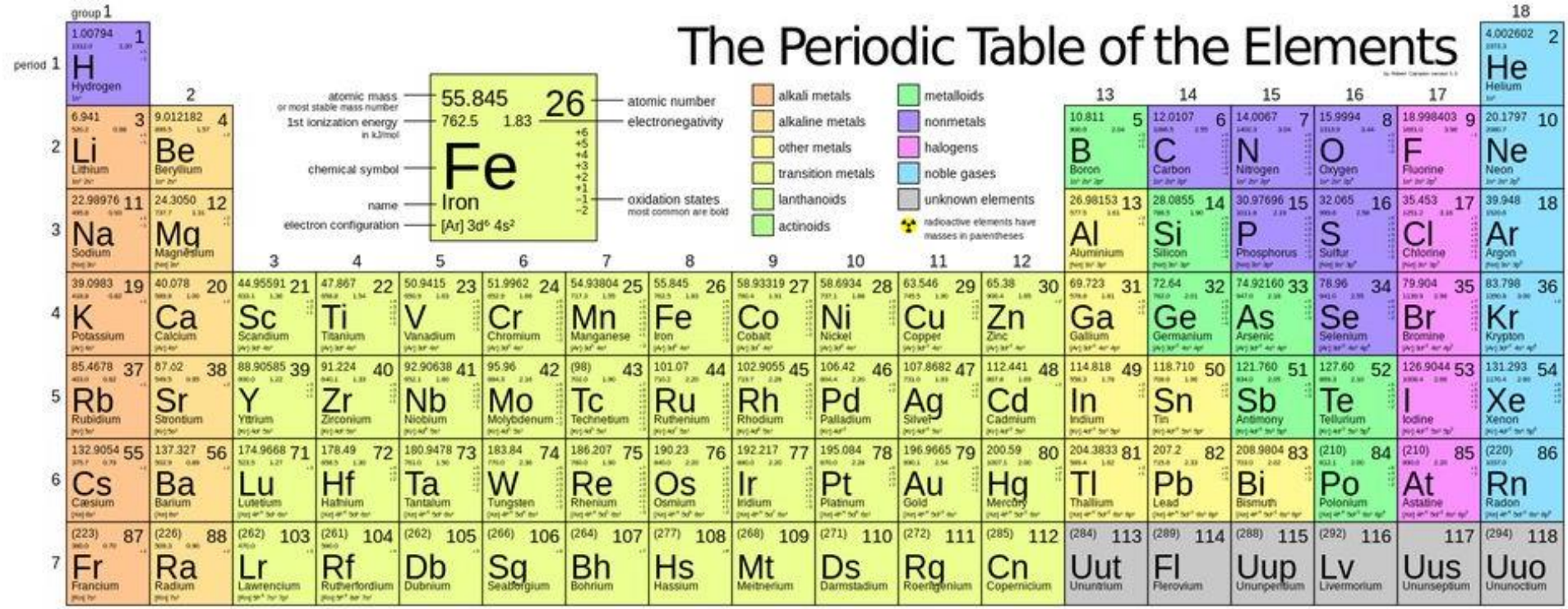
Chemistry is central to our understanding of the world around us

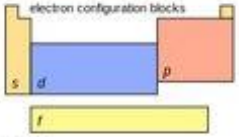
1-1 The Study of Chemistry

Chemistry is the study of matter and the changes that matter undergoes


DO YOU HAVE MASS? DO YOU OCCUPY SPACE?
YOU MATTER.

The Periodic Table of the Elements

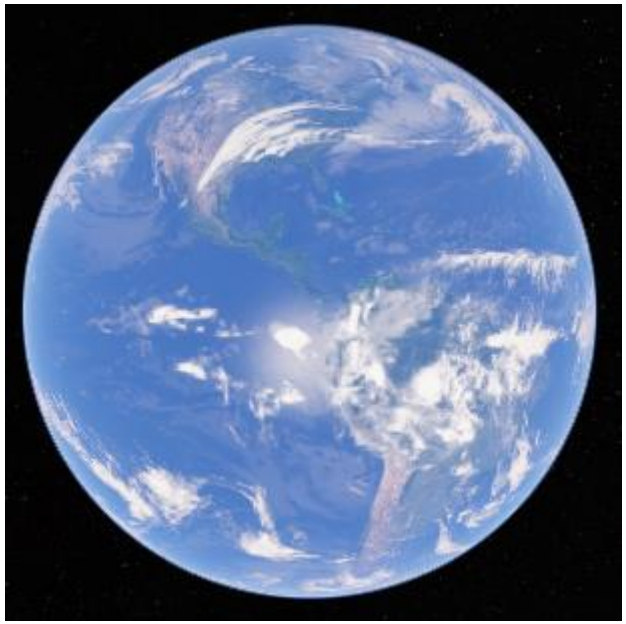


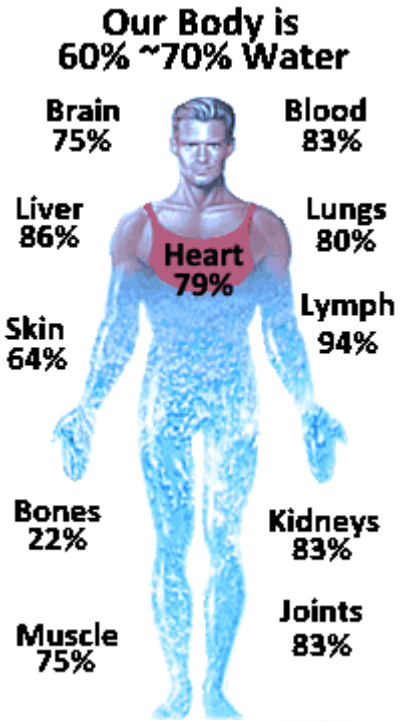


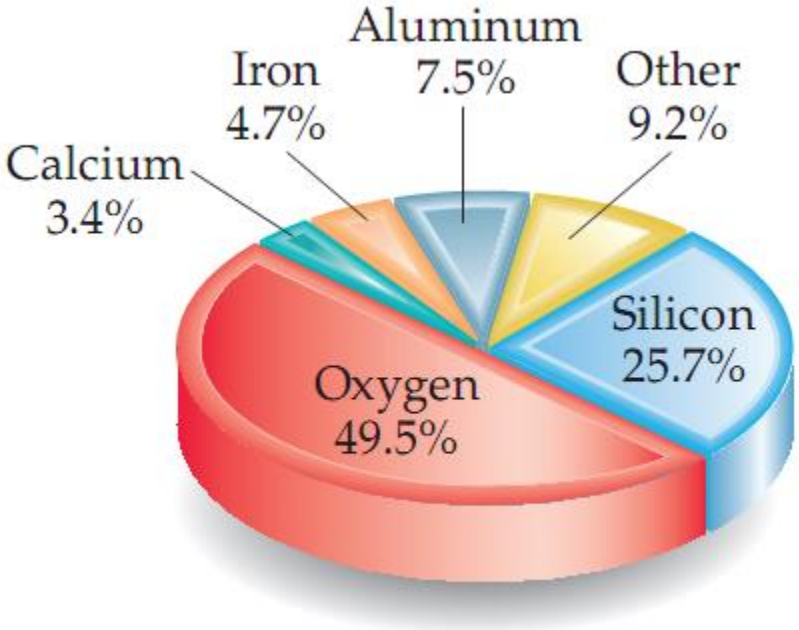
138.9054 57 La Lanthanum	140.116 58 Ce Cerium	140.9076 59 Pr Praseodymium	144.242 60 Nd Neodymium	(145) 61 Pm Promethium	150.36 62 Sm Samarium	151.964 63 Eu Europium	157.25 64 Gd Gadolinium	158.9253 65 Tb Terbium	162.500 66 Dy Dysprosium	164.9303 67 Ho Holmium	167.259 68 Er Erbium	168.9342 69 Tm Thulium	173.054 70 Yb Ytterbium
(227) 89 Ac Actinium	232.0380 90 Th Thorium	231.0358 91 Pa Protactinium	238.0289 92 U Uranium	(237) 93 Np Neptunium	(244) 94 Pu Plutonium	(243) 95 Am Americium	(247) 96 Cm Curium	(247) 97 Bk Berkelium	(251) 98 Cf Californium	(252) 99 Es Einsteinium	(257) 100 Fm Fermium	(258) 101 Md Mendelevium	(259) 102 No Nobelium

notes

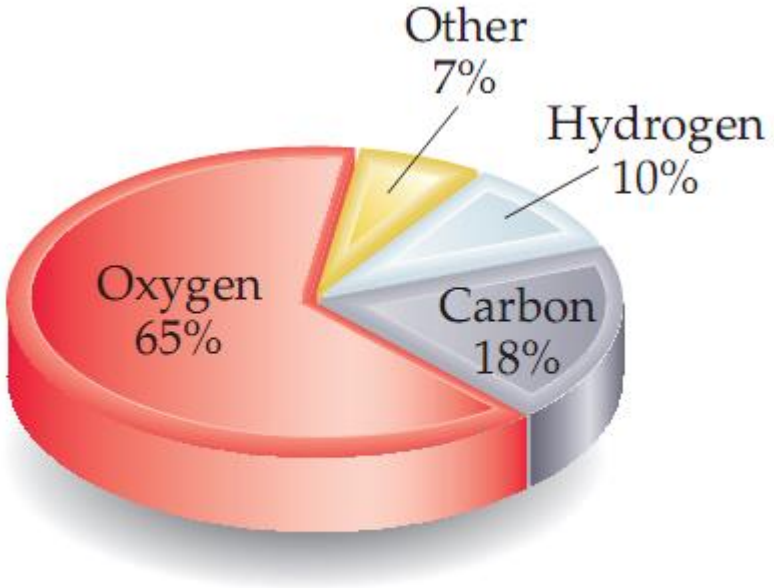
- as of yet, elements 113,115,117 and 118 have no official name designated by the IUPAC.
- 1 kJ/mol = 96.485 eV.
- all elements are implied to have an oxidation state of zero.







Earth's crust



Human body

Atoms

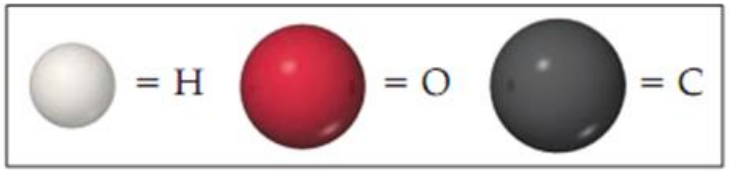
Atoms: the almost infinitesimally small building blocks of matter

Molecules and compounds

Molecule: two or more atoms are joined in specific shapes

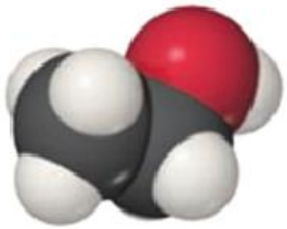
Homonuclear molecule

Oxygen

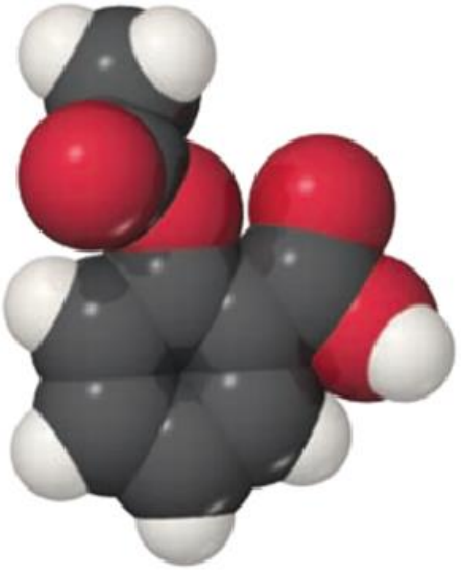


Compound

Water

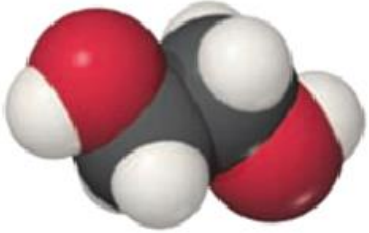


Ethanol



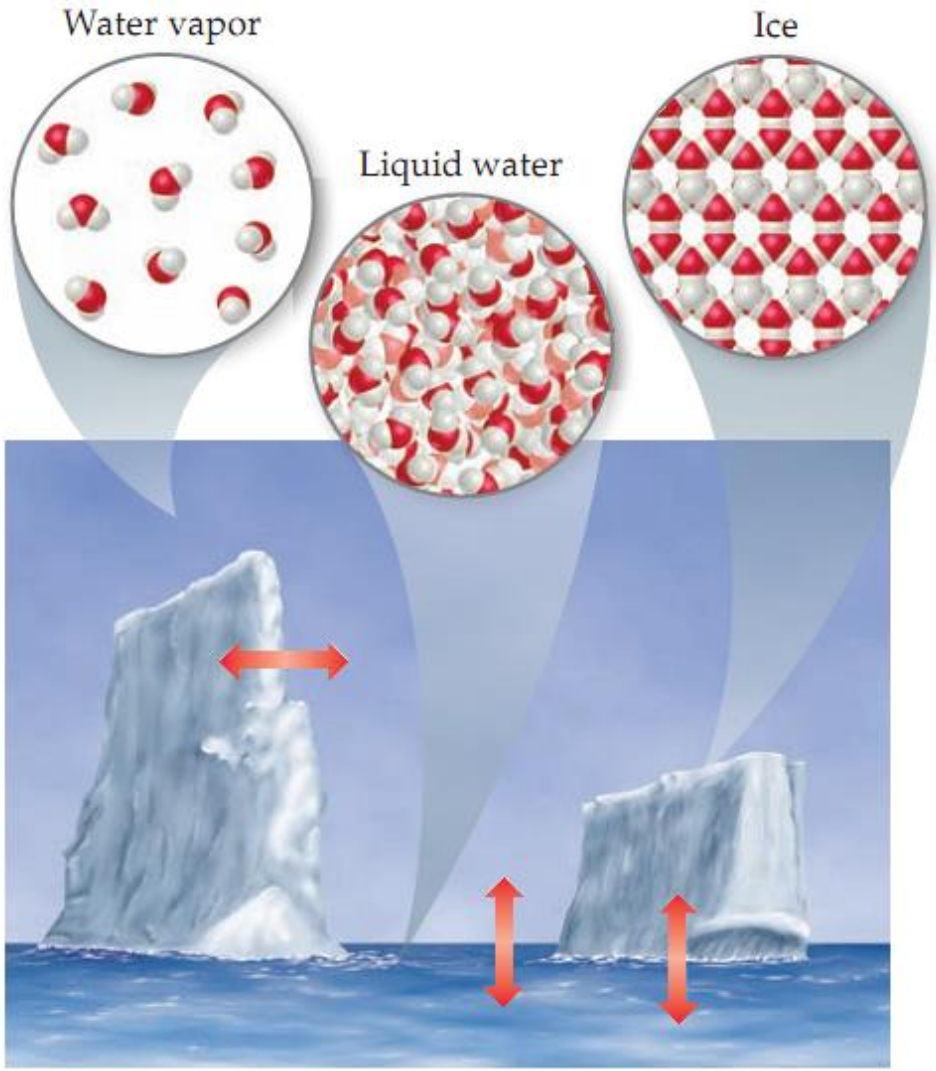
Aspirin

Carbon dioxide



Ethylene glycol

1-2 Classification of Matter

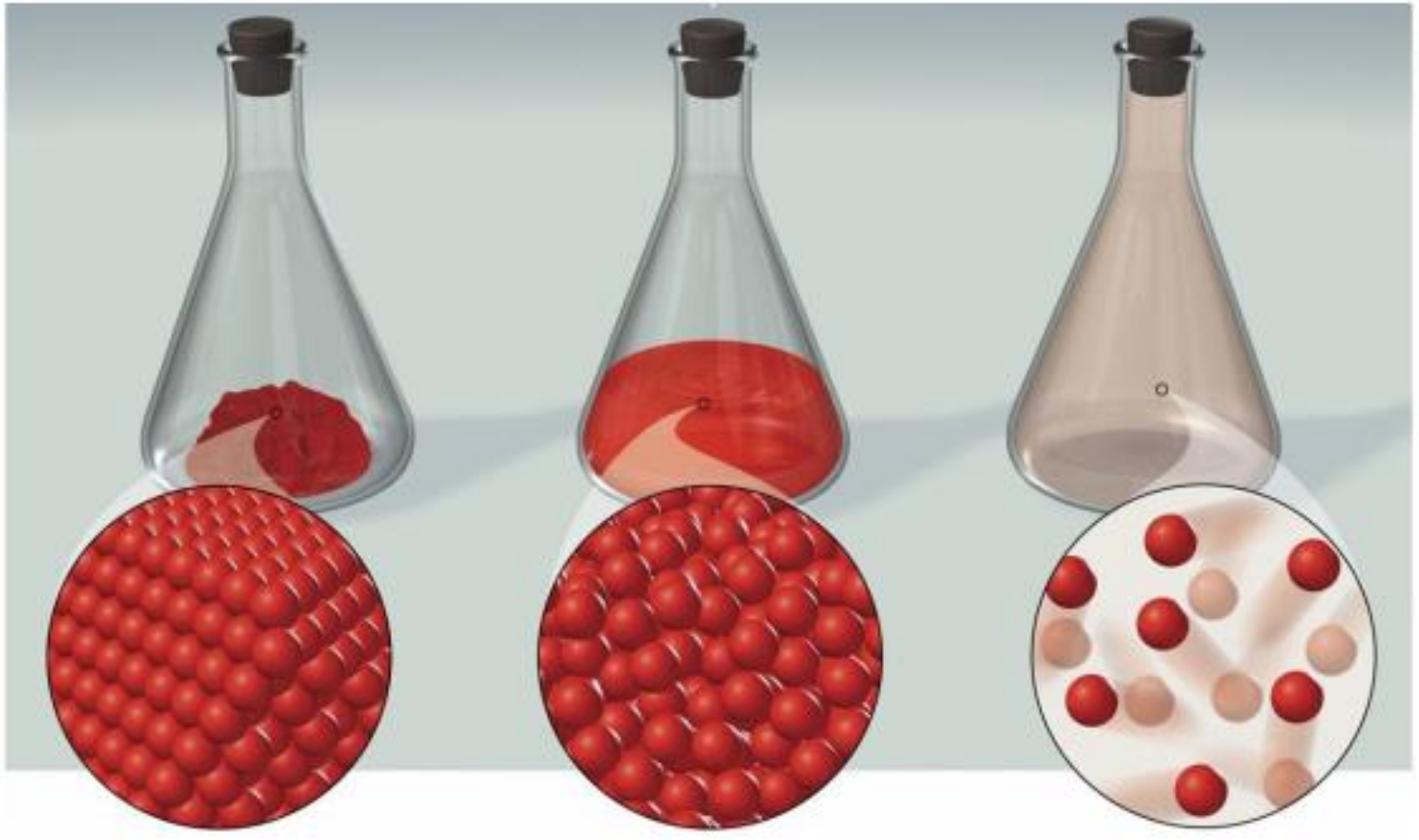


Physical States of Matter

In which state of matter (gas, liquid or solid) are individual molecular furthest apart?

In which one they are the second furthest apart?

In which state are they closest together?



Solids
have a fixed shape and volume

not compressible

Liquids
conform to the shape of a container, but not the volume

not compressible

Gases
take up the shape and volume of a container

compressible

Pure substances

Pure substances: matter that has distinct properties and a composition that does not vary from sample to sample

Diamond (carbon, C)

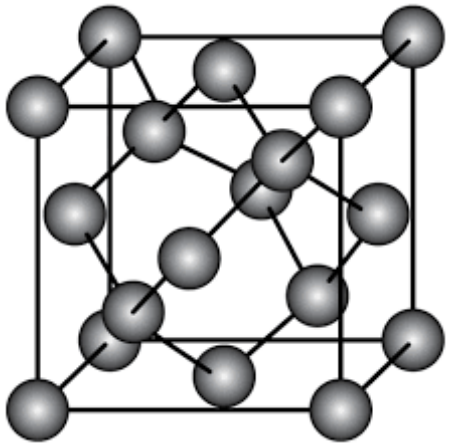
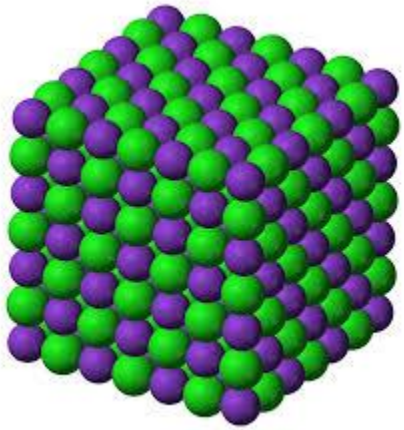


Table salt (sodium chloride, NaCl)

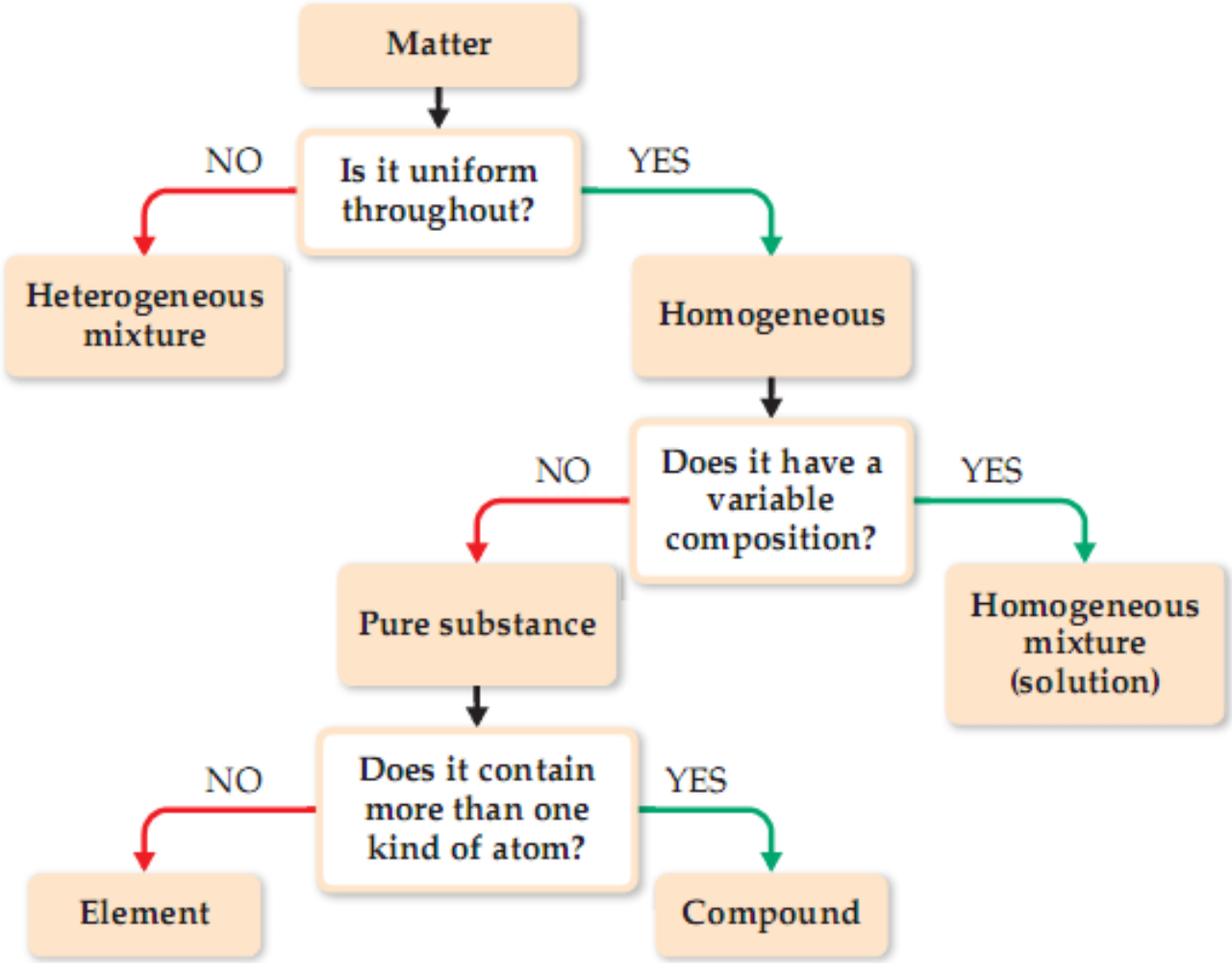


Mixtures

Mixture: collection of two or more pure substances

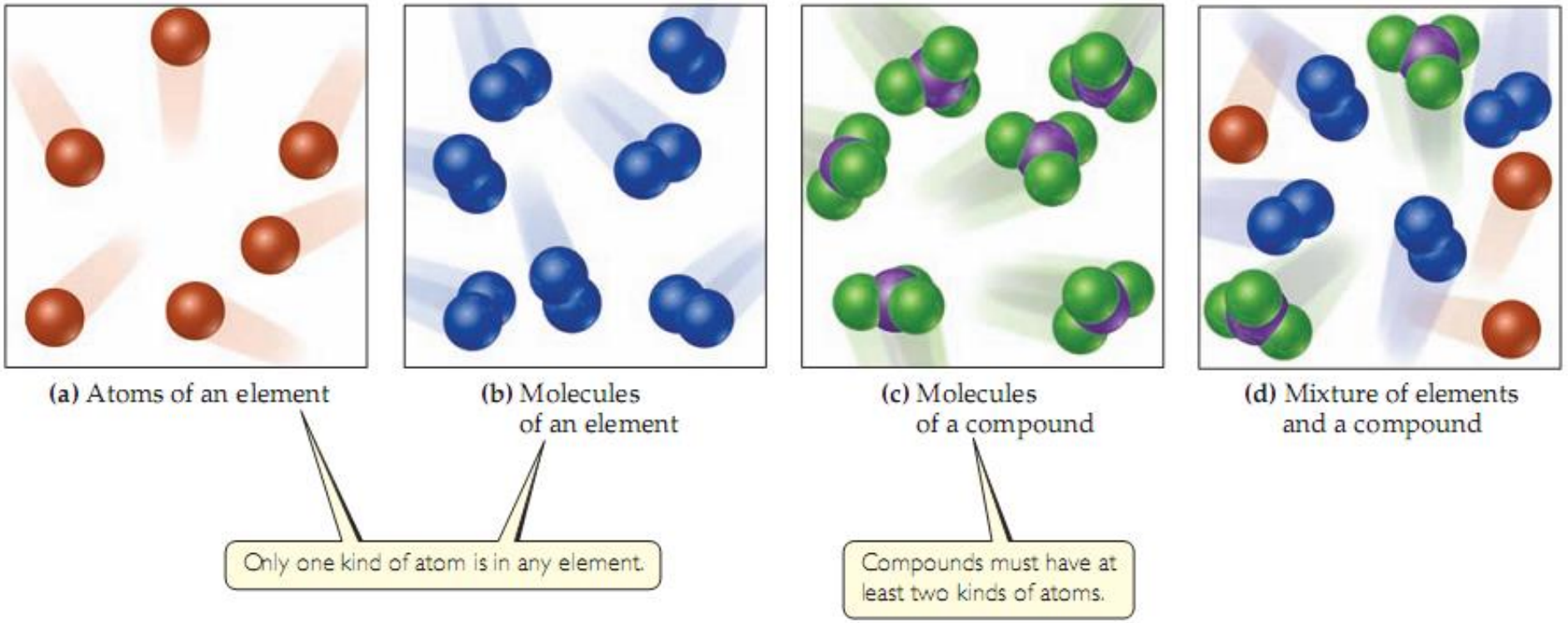
rocks
a heterogeneous mixtures

copper(II) sulfate aqueous solution
a homogeneous mixtures

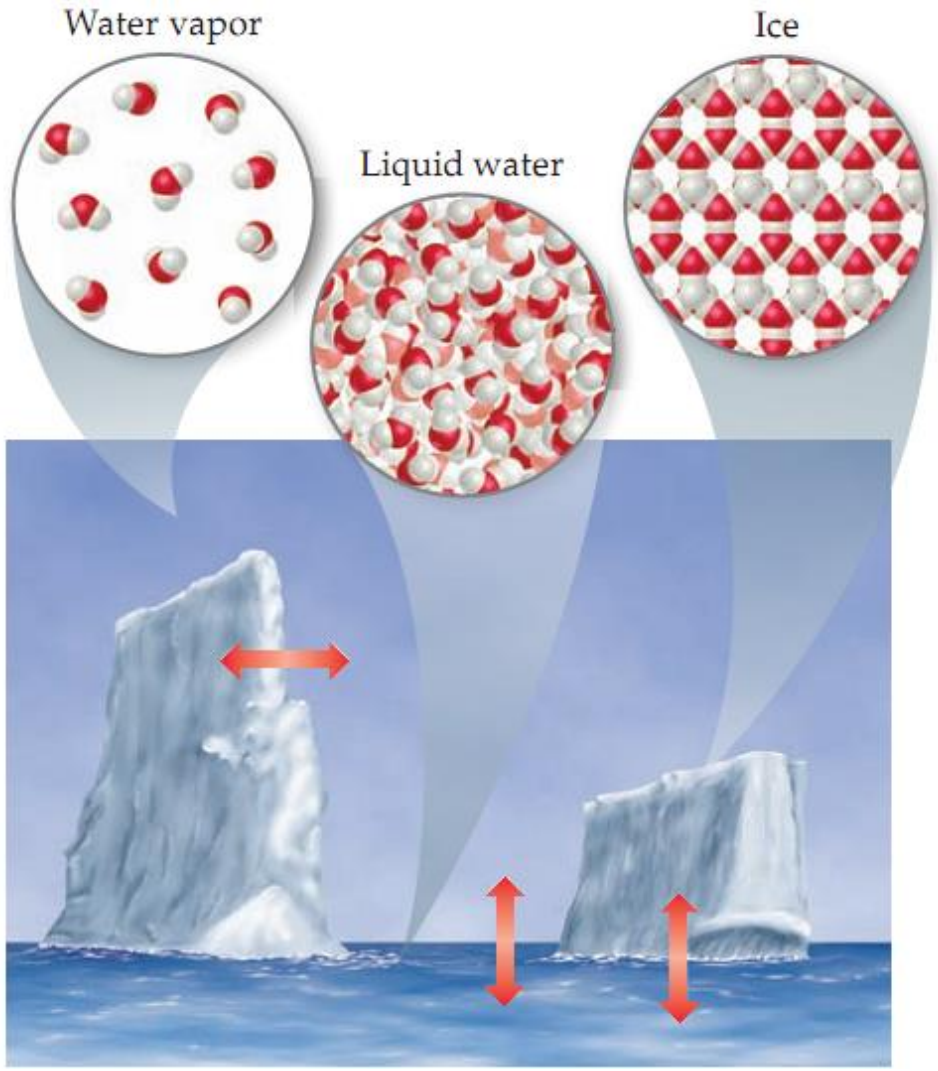


- **Matter** is made of atoms.
- **Atoms** are differentiated as **elements** (118 elements known).
- **Compounds** are comprised of two or more elements.
- **Molecule**s are the smallest units of compounds.

How do the molecules of a compound differ from the molecules of an element?



1-3 Properties of Matter

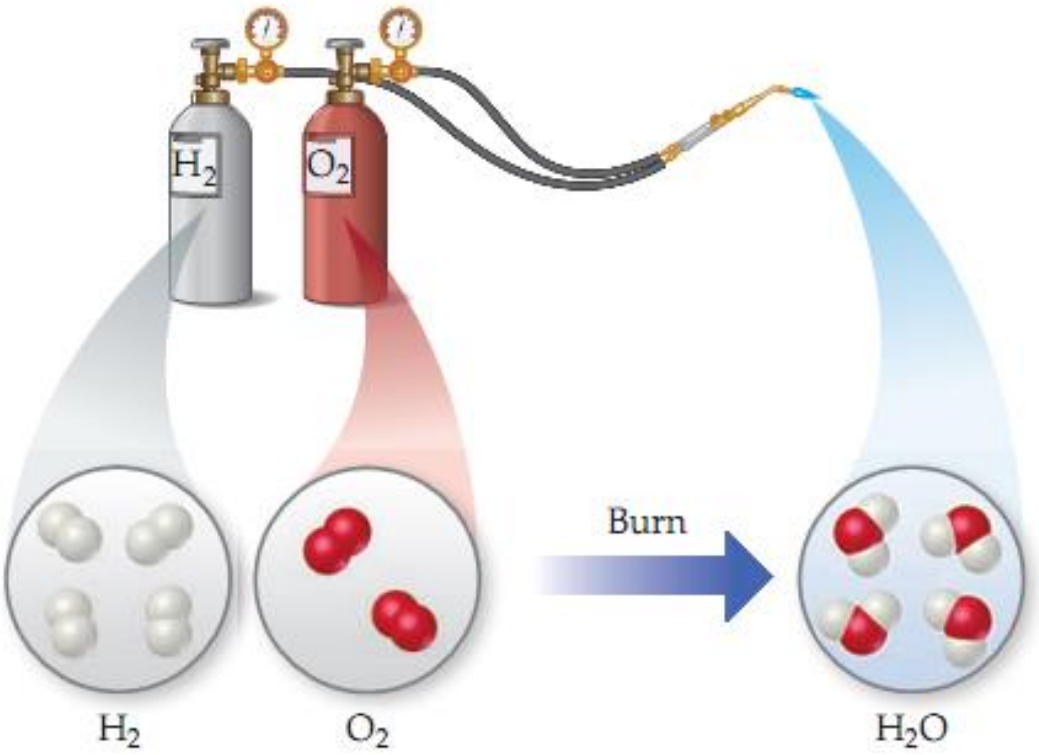


Physical change

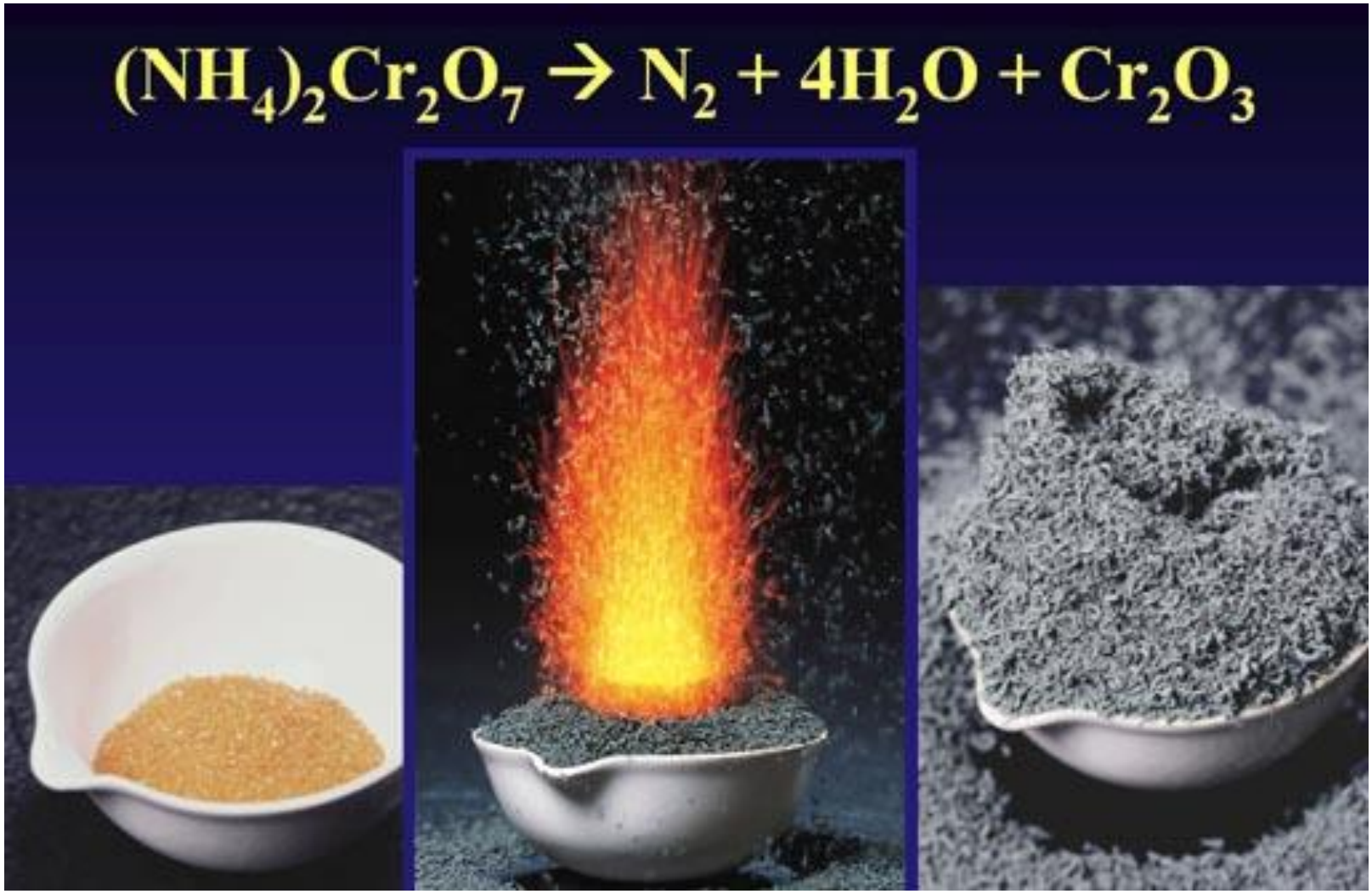
Physical appearance changes but chemical composition does not

Chemical change

Chemical change (also called a **chemical reaction**): a substance is transformed into a chemically different substance



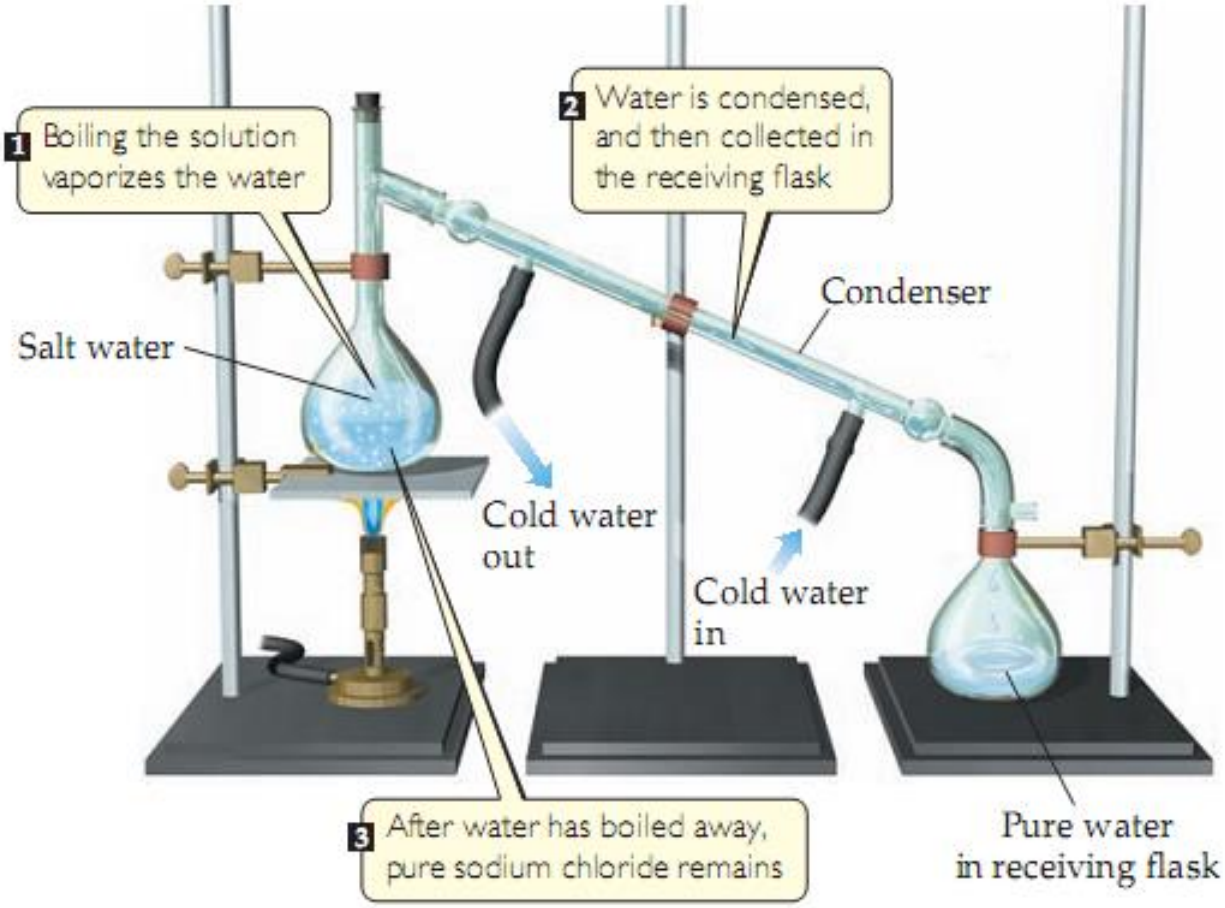
Chemical change – formation of a new compound (water)



Chemical change – decomposition of a compound (ammonium chromate)

Separation of Mixtures

Physical change : a substance changes its physical appearance but not its composition



Separation of a mixture (salt water) by distillation

EXAMPLE

Which of the following represents a physical change?

a. *Alkanes burn spontaneously.*

b. *The sublimation of CO_2.*

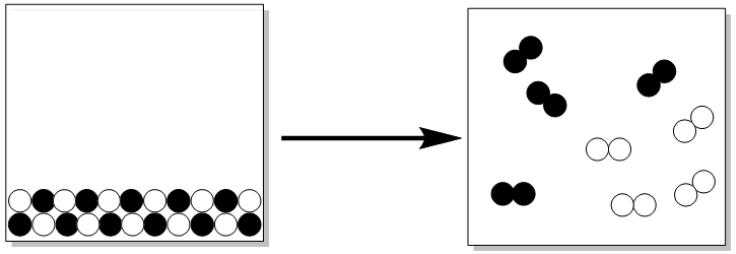
c. *$2\ H_2\ (g) + \ O_2\ (g) \rightarrow 2\ H_2O\ (g)$*

d. *The rusting of a car.*

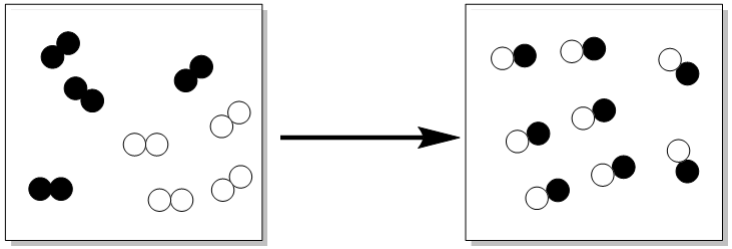
EXAMPLE

Determine which of the following represents a physical change and a chemical change.

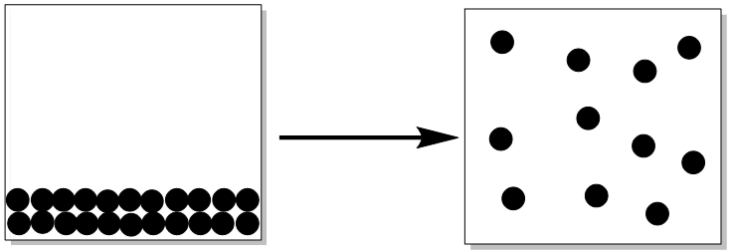
a.



b.

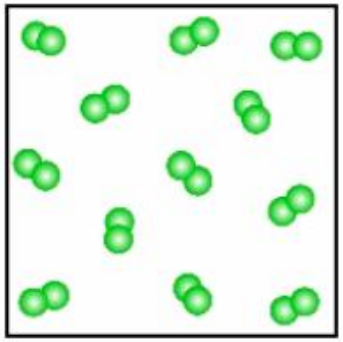


c.

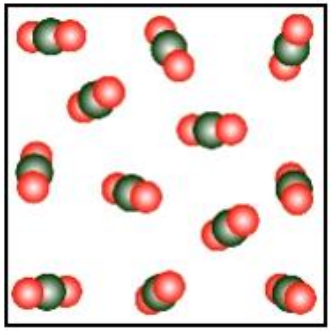


EXAMPLE

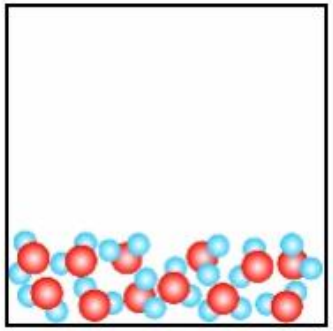
Answer each of the following questions based on the images provided below.



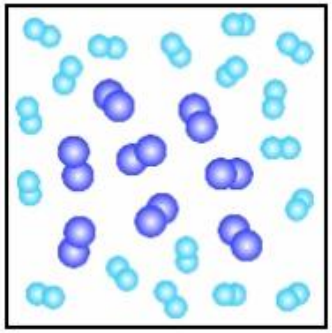
1



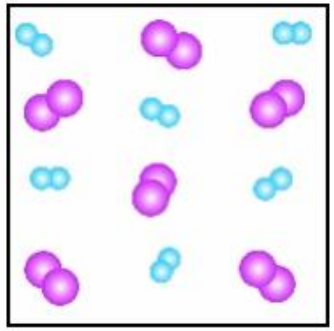
2



3



4



5

a) Which images represents an elemental gas?

b) Which images represents a heterogeneous mixture?

c) Which images represents a liquid?

EXAMPLE

Identify each of the following homogeneous or heterogeneous mixture

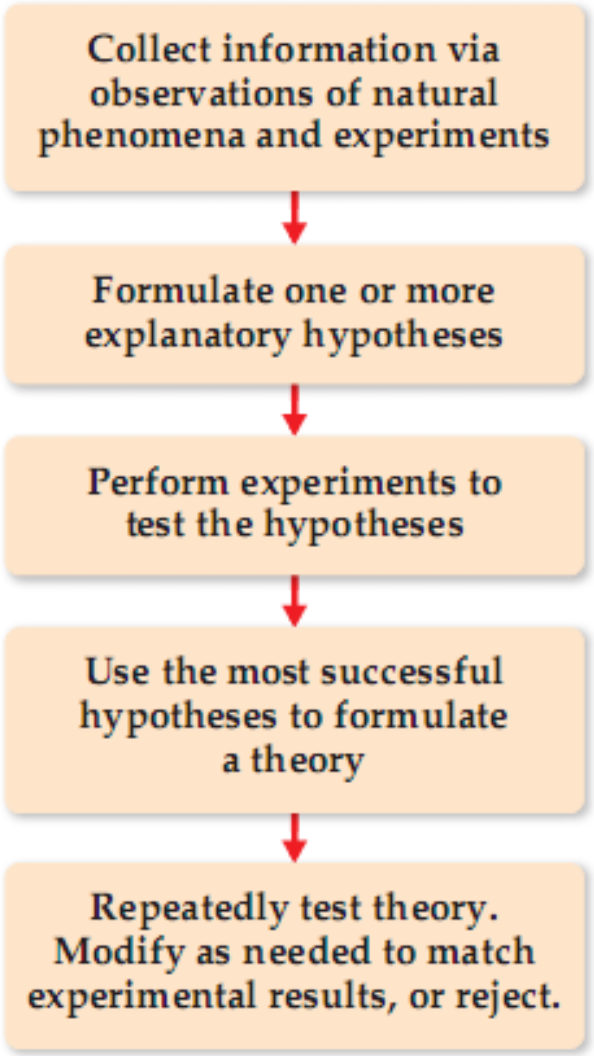
a) Wood

b) Tap water

c) Dirt

d) Air

1-4 The Measurement of Matter



Scientific Method

Table 1.4 SI Base Units

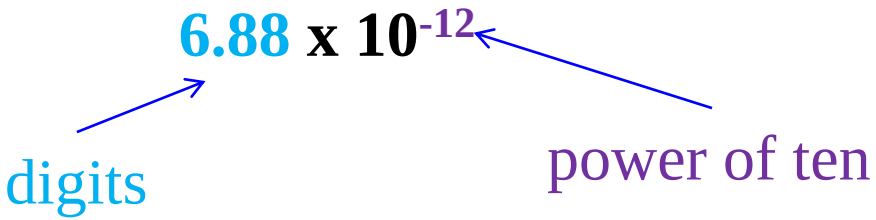
Physical Quantity	Name of Unit	Abbreviation
Mass	Kilogram	kg
Length	Meter	m
Time	Second	s or sec
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A or amp
Luminous intensity	Candela	cd

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

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

Scientific Notation

Scientific notation is used to turn small or large, inconvenient numbers into manageable ones



the decimal point placed after the first digit

Six point eighty eight times ten to the minus twelfth

EXAMPLE

Convert the following numbers into scientific notation

a. 377,000

b. 0.000101

c. 707.82

d. 161.00×10^{7}

Mass

- Mass is the **quantity** of matter in an object.
- Weight is the force of gravity on an object

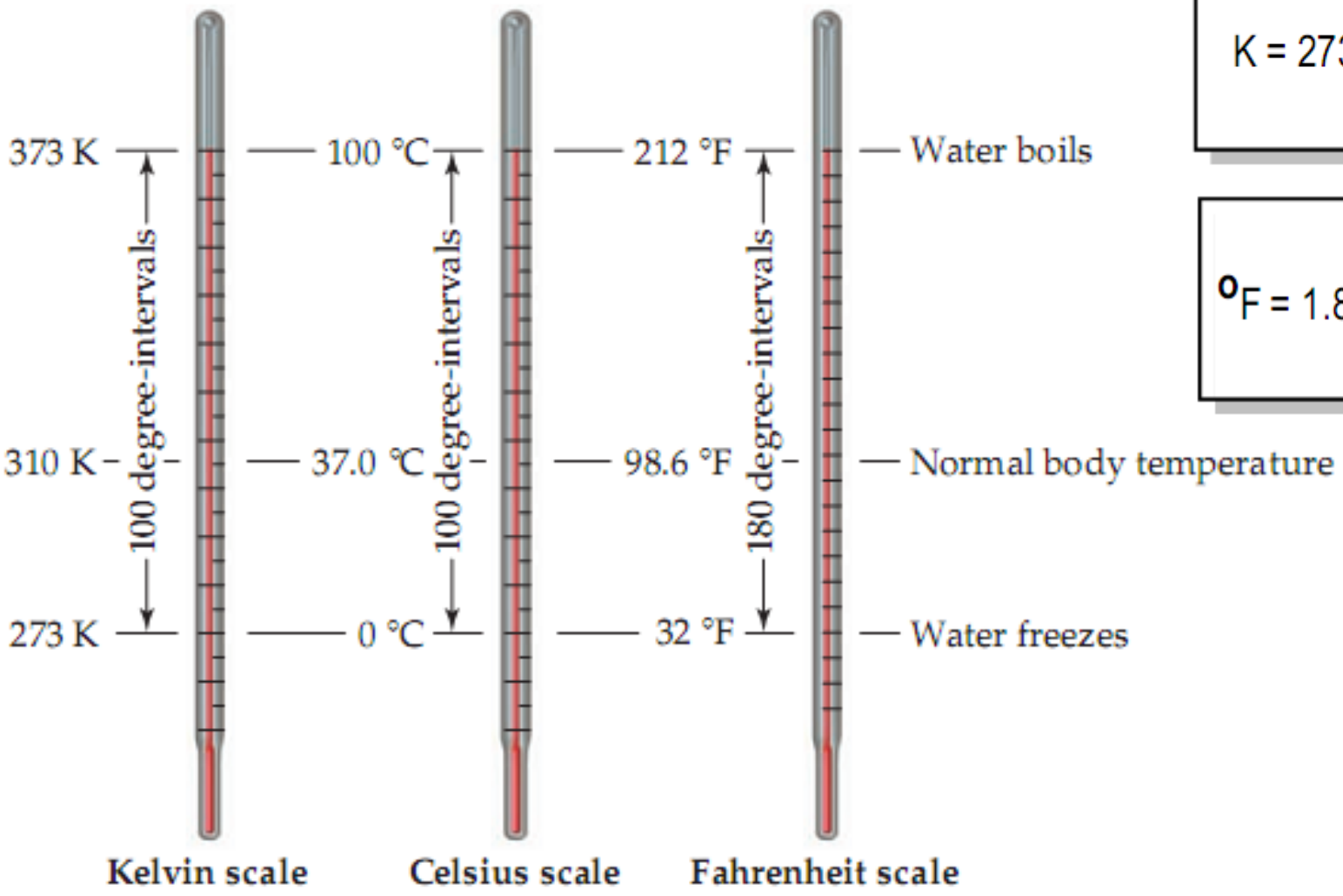
$W \propto m$ $W = g \cdot m$

Temperature

Temperature is a measure of the hotness or coldness of an object

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

${}^{o}F = 1.8\,({}^{o}C) + 32$



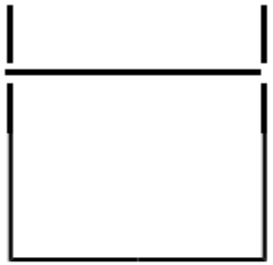
- Temperature is a measure of thermal energy in a substance, which is independent on the amount of matter.
  - This is an intensive property
  - Other examples of intensive properties: boiling point, melting point, color,…

- Heat is a form of thermal energy, which is dependent on the amount of matter.
  - This is an extensive property
  - Other examples of extensive properties: mole, mass, volume,…

EXAMPLE

Which of the following has the greater amount of heat?

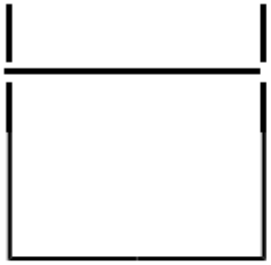
a.



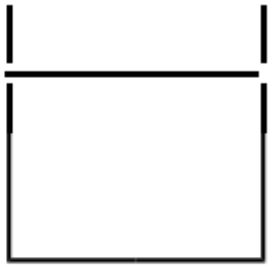
30 g H_2O at 50°C

300 g H_2O at 50°C

b.

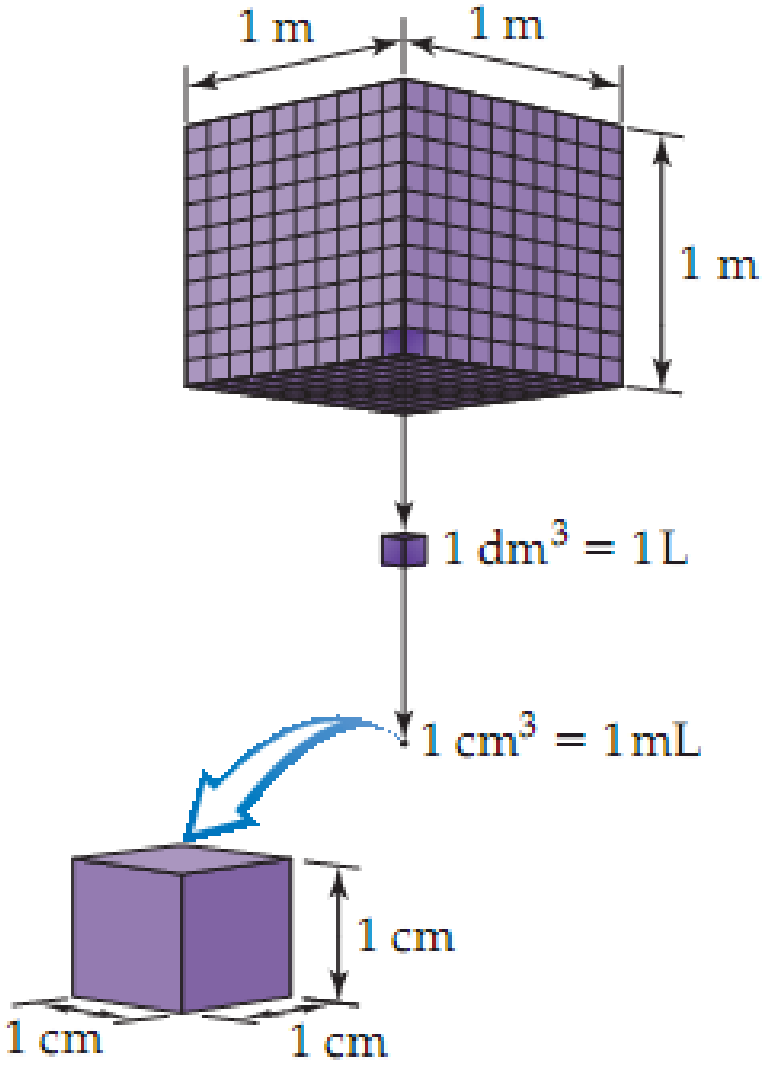


30 g H_2O at 50°C



30 g H_2O at 100°C

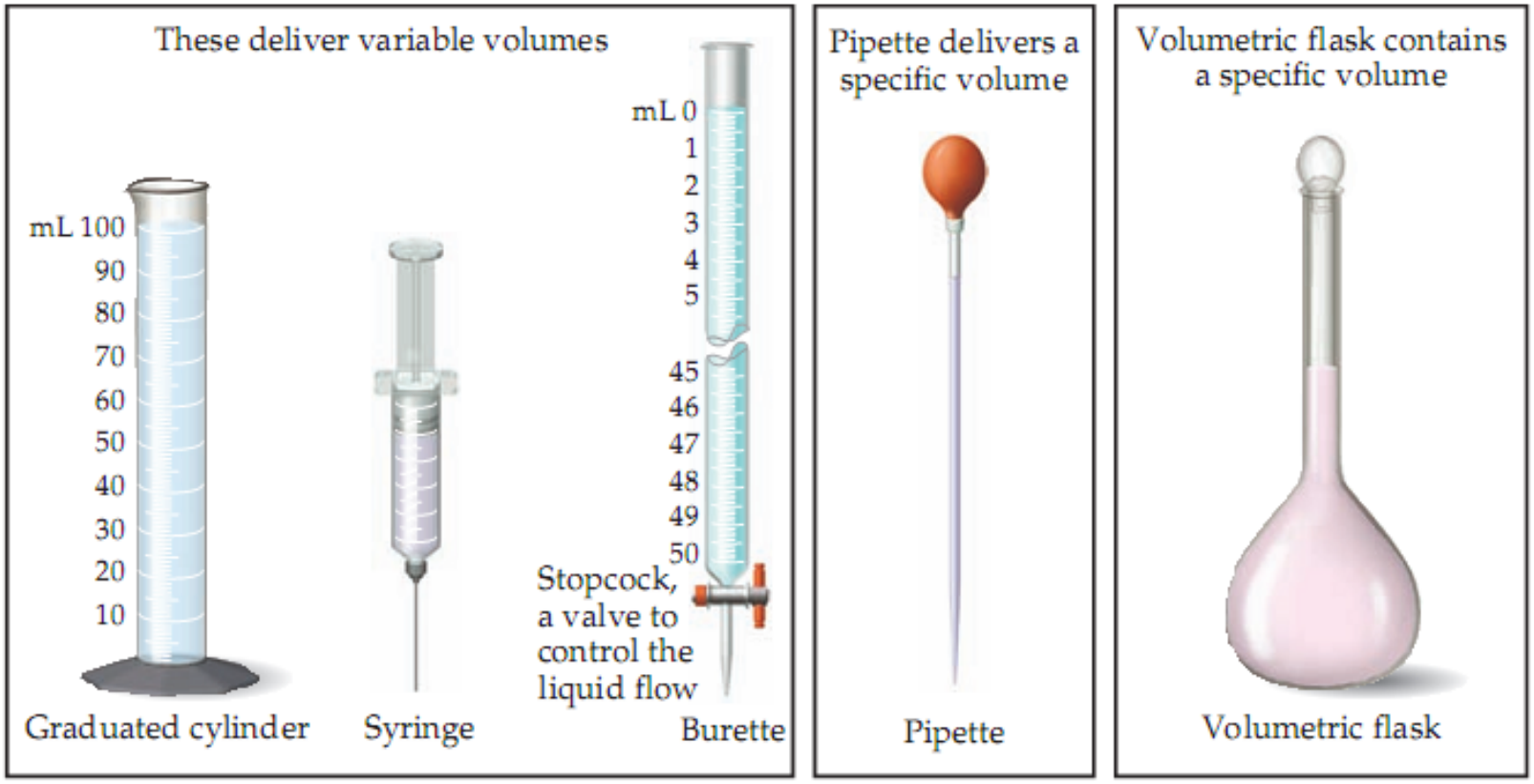
Volume



Density

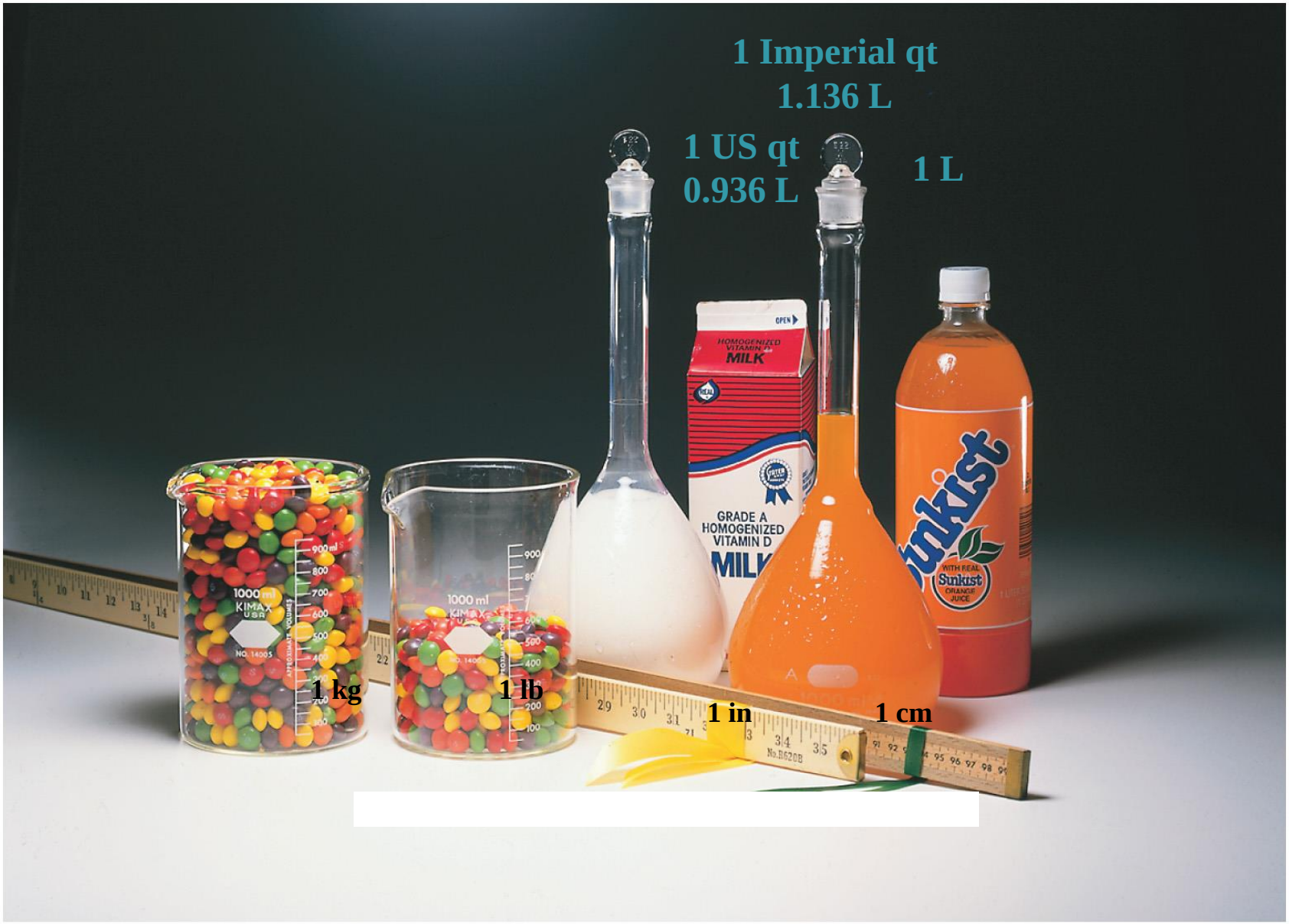
Density is the amount of mass in a unit volume of a substance.

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



Common volumetric glassware for measuring volume of liquids

SI and non-SI Units Compared



Units

S.I. Units

Length	meter, m
Mass	Kilogram, kg
Time	second, s
Temperature	Kelvin, K
Quantity	Mole, 6.022×10^{23} mol^{-1}

Derived Quantities

Force	Newton, kg m s^{-2}
Pressure	Pascal, kg m^{-1} s^{-2}
Energy	Joule, kg m^2 s^{-2}

Other Common Units

Length	Angstrom, Å, 10^{-8} cm
Volume	Liter, L, 10^{-3} m^3
Energy	Calorie, cal, 4.184 J
Pressure	

1 Atm = 1.064×10^2 kPa

1 Atm = 760 mm Hg

Density and Percent Composition

$$\delta = m/V$$

$$m = V\delta \qquad V = m/\delta$$

g/mL

Mass and volume are extensive properties

Density is an intensive property

Density in Conversion Pathways

What is the mass of a cube of osmium that is 1.25 inches on each side?

Have volume, need density = $22.48 g/cm^3$

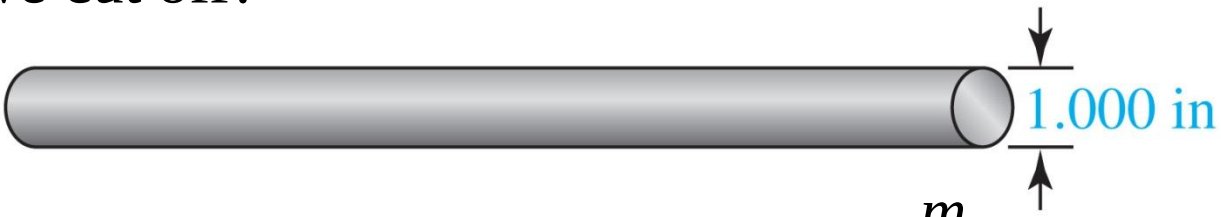
(converts in. to cm) (converts cm to cm^3) (converts cm^3 to g osmium)

$$\text{? g osmium} = \left[1.25 \text{ in.} \times \frac{2.54 \text{ cm}}{1 \text{ in.}}\right]^3 \times \frac{22.48 \text{ g osmium}}{1 \text{ cm}^3} = 719 \text{ g osmium}$$

EXAMPLE

Relating Mass, Volume and Density

The stainless steel in the solid cylindrical rod pictured below has a density of 7.75 g/cm^3. If we want a 1.00 kg mass of this rod, how long a section must we cut off?



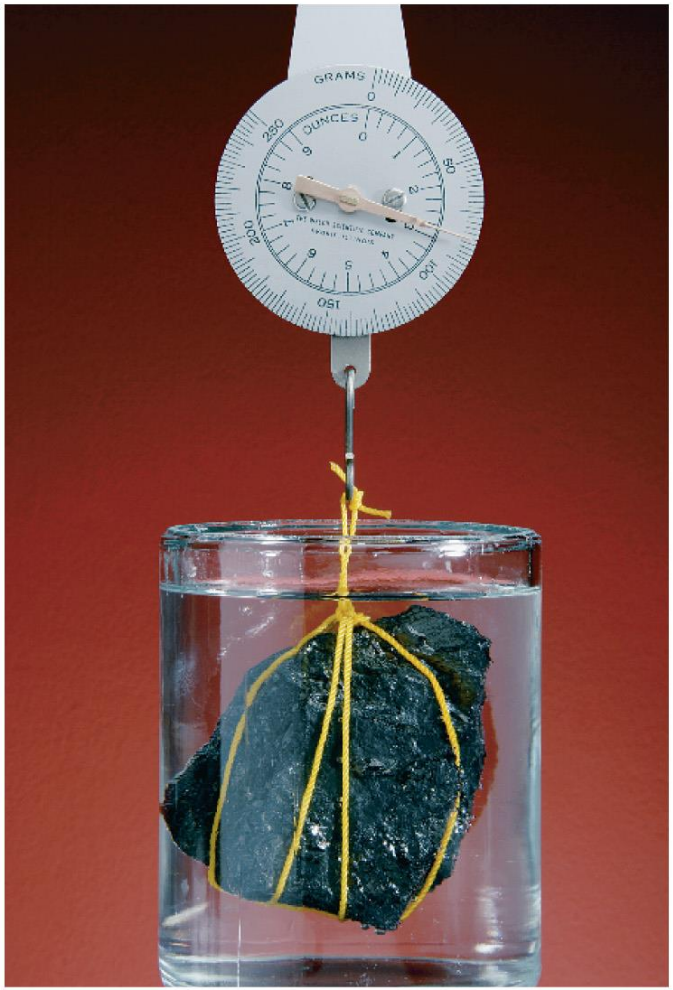
Calculate the Volume needed $V = \frac{m}{d} = m \times \frac{1}{d}$

$$V = = (1.00\text{kg})(1000\text{g/kg}) \times \frac{1\ \text{cm}^3}{7.75\ \text{g}} = 129\ \text{cm}^3$$

Calculate the Length $V = h\,\pi r^2$ $h = \frac{V}{\pi r^2}$

$$h = \frac{V}{\pi r^2} = \frac{129\ \text{cm}^3}{(3.1415)\{(0.5)(1.000\ \text{in})(2.54\ \text{cm/in})\}^2} = 25.5\ \text{cm}$$

Measuring Volume of an Irregular Object



1-5 Uncertainty in Measurement

Good accuracy
Good precision

Poor accuracy
Good precision

Poor accuracy
Poor precision

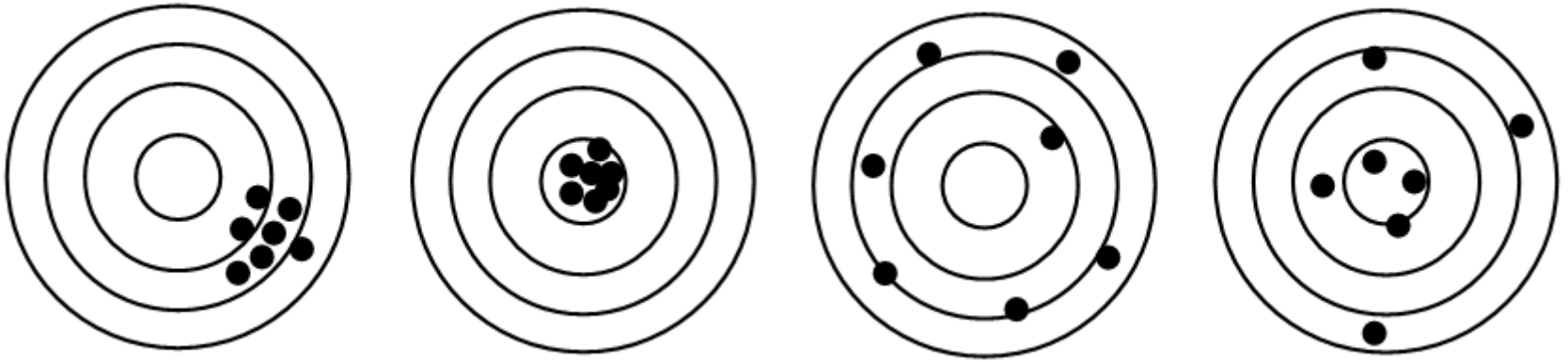
- Precision
  - Reproducibility of a measurement.
- Accuracy
  - How close to the real value.
- Systematic errors.
  - Constantly lower
  - Constantly higher
- Random errors
  - Limitation in reading a scale.

Precision

Reproducibility	± 0.1 g	± 0.0001 g
Precision	low	high

EXAMPLE

Which of the 4 following images is not precise and not accurate?



1 2 3 4

EXAMPLE

A student must measure the weight of a sodium bicarbonate compound, $NaHCO_3$, and obtains the following measurements: 23.12 g, 23.08 g and 23.17g. If the true weight of the compound is 18.01 g what can be said about the student's results?

a. *They are accurate and precise.*

b. *They are accurate, but not precise.*

c. *They are neither accurate or precise.*

d. *They are not accurate, but precise.*

Standard Deviation

The standard deviation measures **how close** data results are in relation to the mean, or average, value.

$$SD = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}}$$

x_i = Observed value

$\bar{x}$ = Mean value

n = Number of observations

EXAMPLE

Calculate the standard deviation for the following results:

a. *5.29, 5.35, and 5.31*

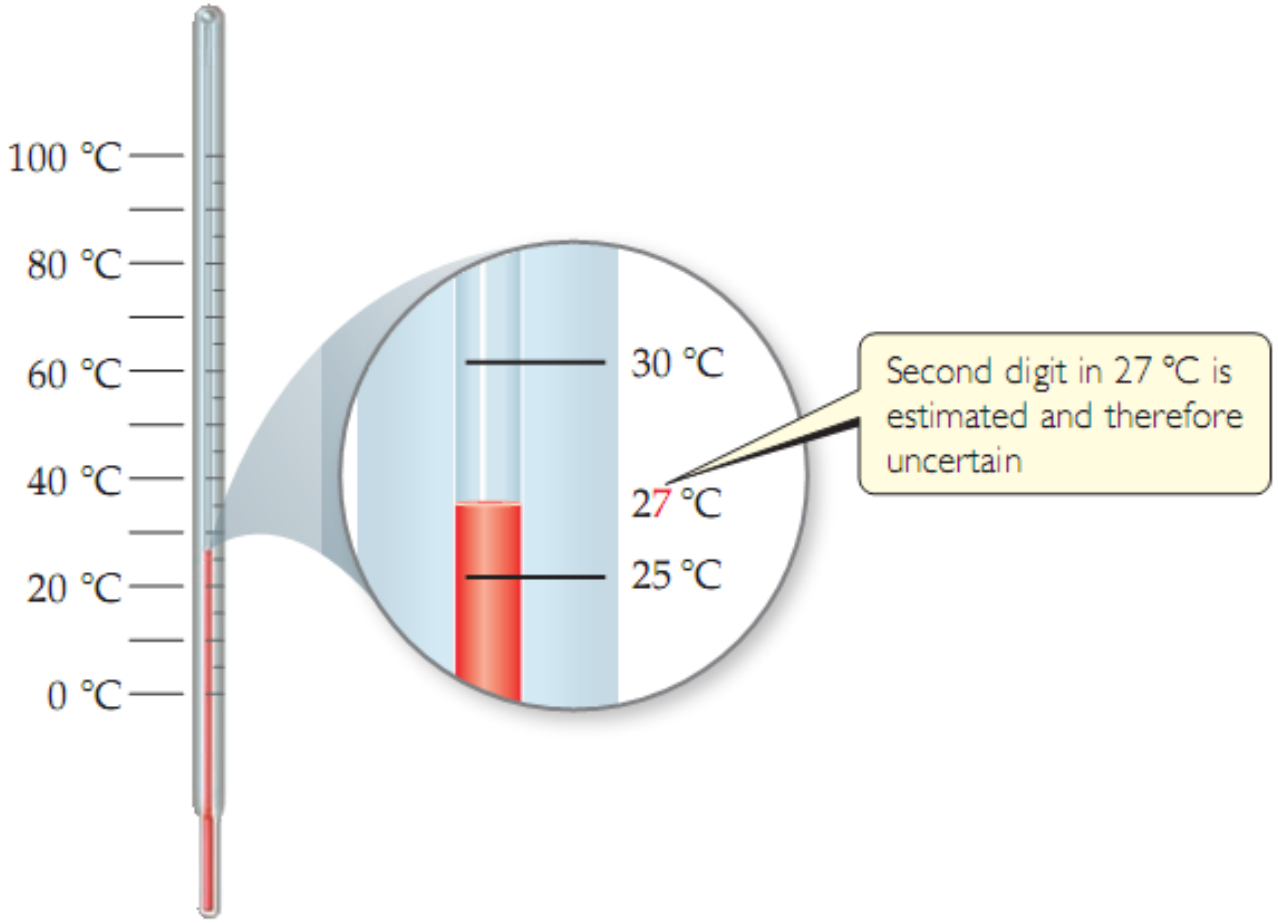
b. *0.39, 0.061, and* 5.3×10^{-2}

Now, answer this question:

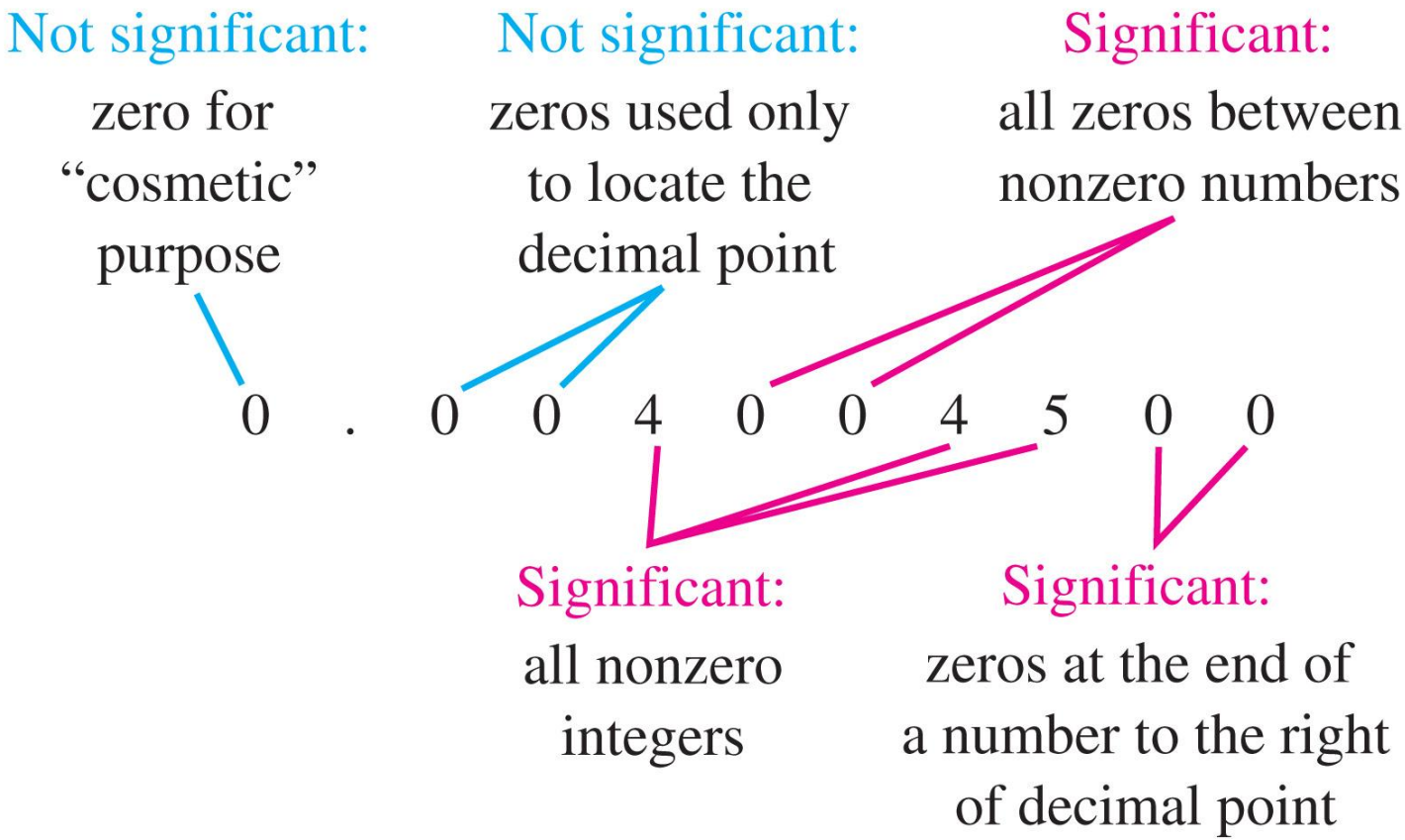
How tall are you?

Significant Figures

All digits of a measured quantity, including the uncertain one, are called significant figures



Significant Figures



EXAMPLE

How many sig figs does each number contain?

a. *0.0000185 m*

b. *749 mol*

c. *17.3×10^3 mL*

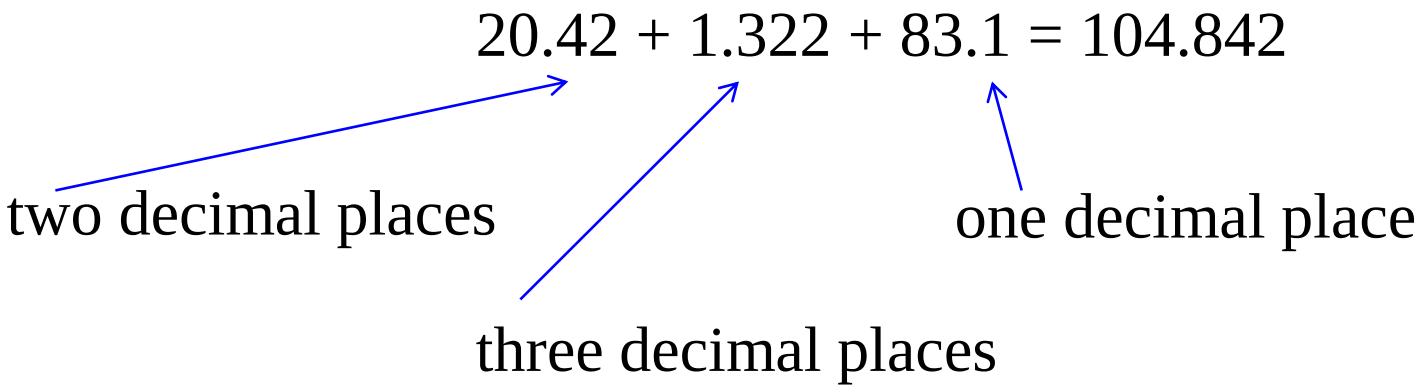
d. *100 min*

e. *0.0010050 kg*

f. *1560 mol*

Significant figures in calculation

For **addition and subtraction**, the result has the same number of decimal places as the measurement with the **fewest decimal places**



We report the result as **104.8** because 83.1 has only one decimal place

Significant figures in calculation

For **multiplication and division**, the result contains the same number of significant figures as the measurement with the **fewest significant figures**

Area = (6.221 cm)(5.2 cm) = 32.3492 cm^2 => round off to 32 cm^2

four significant figures

two significant figures

We report the result as **32 cm^2** because 5.2 has two significant figures

Check it at https://www.omnicalculator.com/math/sig-fig

EXAMPLE

Perform the following calculation to the right number of sig figs:

a. (3.16) x (0.003027) x (5.7 x 10^{-3})

0.000054522324 = 5.4522324 *10^{-5} = **5.5*10^{-5}**

b.

2.628×10^{6}

6.281×10^{4}

$+ 0.827 \times 10^{7}$

10960180 = 1.0960180 *10^{7} = **1.10 x 10^{7}**

EXAMPLE

Perform the following calculation to the right number of sig figs:

a. $(3.16) \times (0.003027) \times (5.7 \times 10^{-3})$

$= 5.5 \times 10^{-5}$

b.

$$2.628 \times 10^{6}$$
$$6.281 \times 10^{4}$$
$$+\ 0.827 \times 10^{7}$$

0.110×10^{8}

1.10×10^{7}

Significant figures in calculation

When a calculation involves two or more steps and you write answers for intermediate steps, retain at least one nonsignificant digit for the intermediate answers.