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GENERAL CHEMISTRY I

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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

- 1-1 The Study of Chemistry
- 1-2 Classification of Matter
- 1-3 Properties of Matter
- 1-4 Units of Measurement: SI (Metric) System
- 1-5 Uncertainties in Scientific Measurements
- 1-6 Significant Figures

Nutrition Facts

Serving Size 12 fl oz (360 mL)

Servings Per Container 6

Amount Per Serving

Calories 140

% Daily Value*

Total Fat 0g 0%

Sodium 45mg 2%

Total Carbohydrate 39g 13%

Sugars 39g

Protein 0g

Not a significant source of calories from fat, saturated fat, trans fat, cholesterol, dietary fiber, vitamin A, vitamin C, calcium and iron.

*Percent Daily Values are based on a 2,000 calorie diet.



Chemistry is all around us

Energy

Solar panels are composed of specially treated silicon.



Biochemistry

The flash of the firefly results from a chemical reaction in the insect.



Technology

LED's (light emitting diodes) are formed from elements such as gallium, arsenic and phosphorus.



Chemistry

Medicine

Connectors and tubing for medical procedures such as intravenous injections are made from plastics highly resistant to chemical attack.



Chemistry is central to our understanding of the world around us

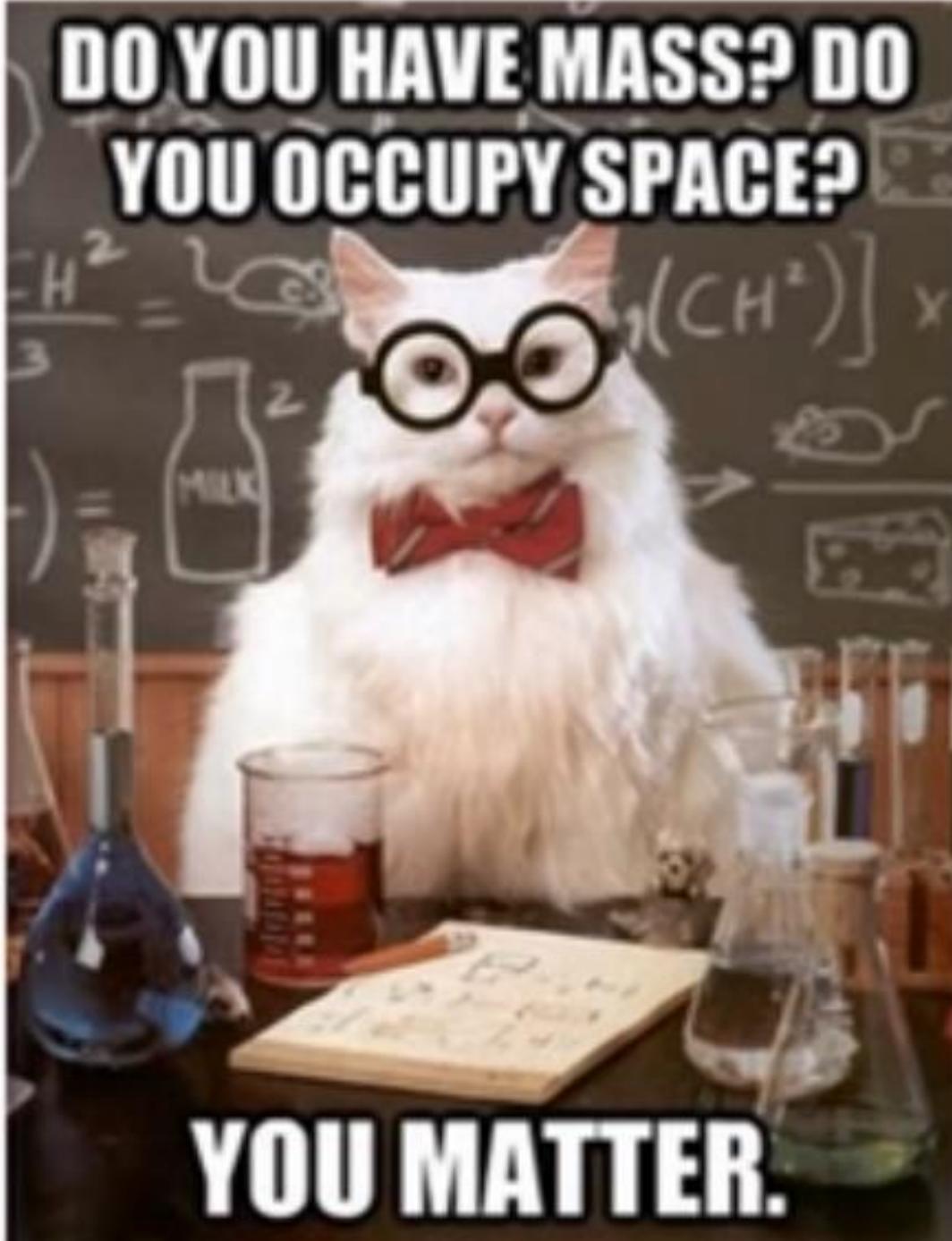
1-1 The Study of Chemistry



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

**DO YOU HAVE MASS? DO
YOU OCCUPY SPACE?**

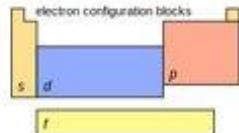
YOU MATTER.



The Periodic Table of the Elements

18

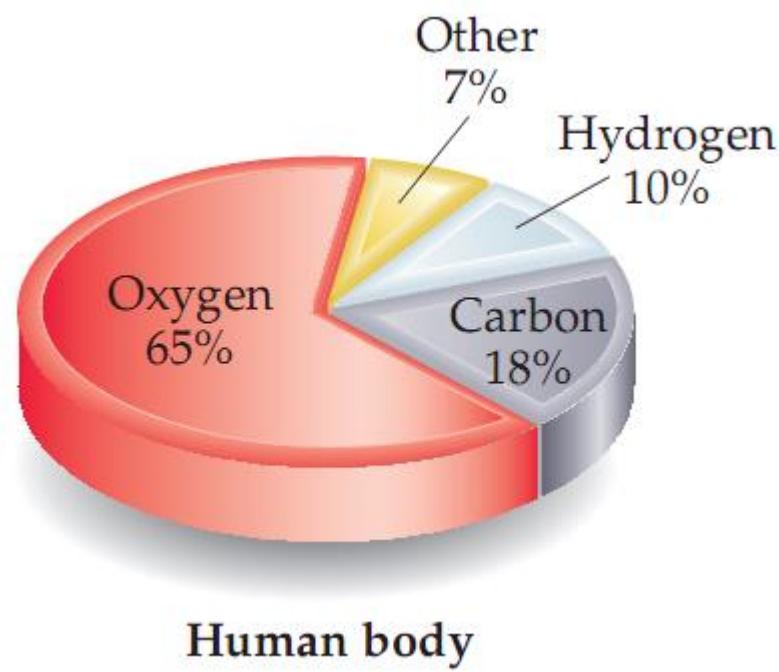
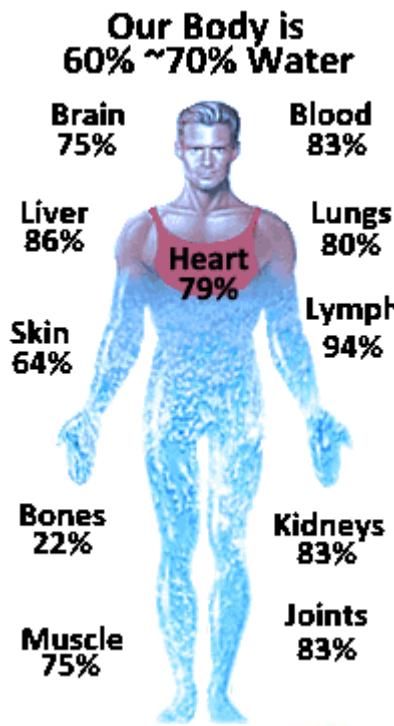
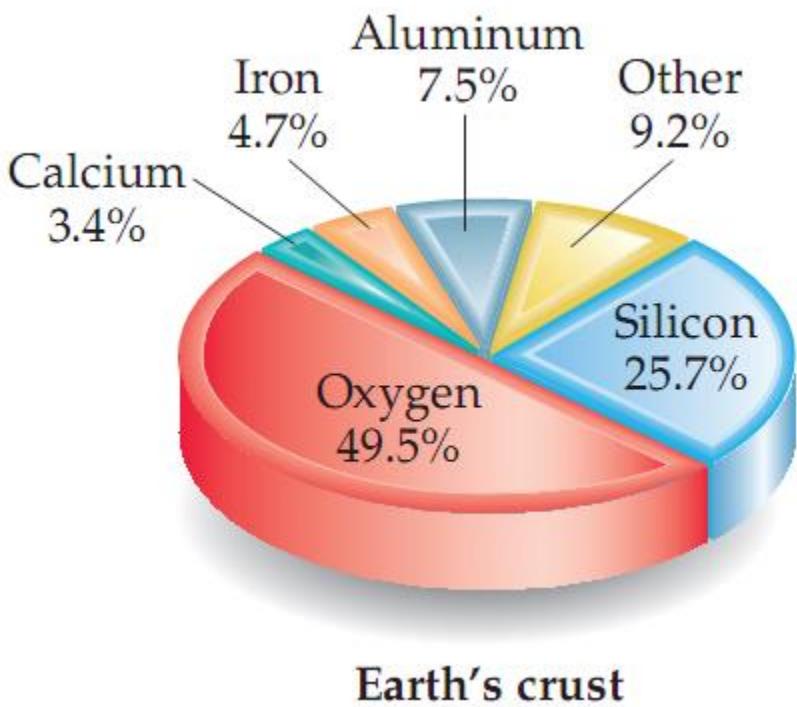
The image shows the periodic table of elements, version 18. It features a grid of colored boxes representing different element groups: alkali metals (light red), alkaline metals (light blue), other metals (light green), transition metals (yellow-green), lanthanoids (light purple), actinoids (pink), metalloids (orange), nonmetals (purple), halogens (blue), noble gases (light blue), and unknown elements (grey). The table includes element symbols, atomic numbers, atomic masses, and oxidation states. A legend on the left provides detailed information about each element's properties.



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.

138.9054 57 58.1 1.39 La Lanthanum (natr. abt.)	140.116 58 58.4 1.32 Ce Cerium (natr. abt.)	140.9076 59 59.9 1.31 Pr Praseodymium (natr. abt.)	144.242 60 59.8 1.34 Nd Neodymium (natr. abt.)	145) 61 59.5 1.37 Pm Promethium (synth. abt.)	150.36 62 59.5 1.37 Sm Samarium (synth. abt.)	151.964 63 59.4 1.39 Eu Europium (synth. abt.)	157.25 64 59.4 1.39 Gd Gadolinium (synth. abt.)	158.9253 65 59.3 1.39 Tb Terbium (synth. abt.)	162.500 66 59.3 1.39 Dy Dysprosium (synth. abt.)	164.9303 67 59.3 1.39 Ho Holmium (synth. abt.)	167.259 68 59.7 1.25 Er Erbium (synth. abt.)	168.9342 69 59.7 1.25 Tm Thulium (synth. abt.)	173.054 70 59.4 1.24 Yb Ytterbium (synth. abt.)
(227) 89 49.0 1.39 Ac Actinium (synth. abt.)	232.0380 90 59.7 1.30 Th Thorium (synth. abt.)	231.0358 91 59.6 1.30 Pa Protactinium (synth. abt.)	238.0289 92 59.9 1.36 U Uranium (synth. abt.)	(237) 93 59.7 1.36 Np Neptunium (synth. abt.)	(244) 94 59.7 1.36 Pu Plutonium (synth. abt.)	(243) 95 59.6 1.36 Am Americium (synth. abt.)	(247) 96 59.0 1.36 Cm Curium (synth. abt.)	(247) 97 59.0 1.36 Bk Berkelium (synth. abt.)	(251) 98 59.0 1.36 Cf Californium (synth. abt.)	(252) 99 59.0 1.36 Es Einsteinium (synth. abt.)	(257) 100 59.7 1.30 Fm Fermium (synth. abt.)	(258) 101 59.9 1.30 Md Mendelevium (synth. abt.)	(259) 102 59.9 1.30 No Nobelium (synth. abt.)



Atoms

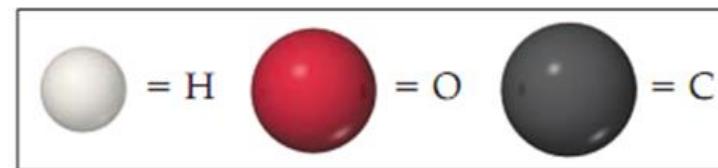
Atoms: the almost infinitesimally small building blocks of matter

The Scale of the Universe 2

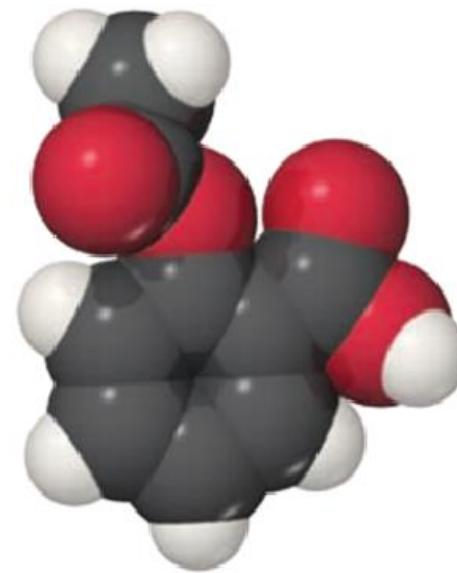
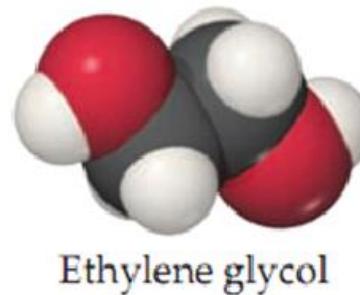
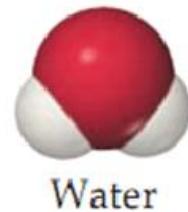
Molecules and compounds

Molecule: two or more atoms are joined in specific shapes

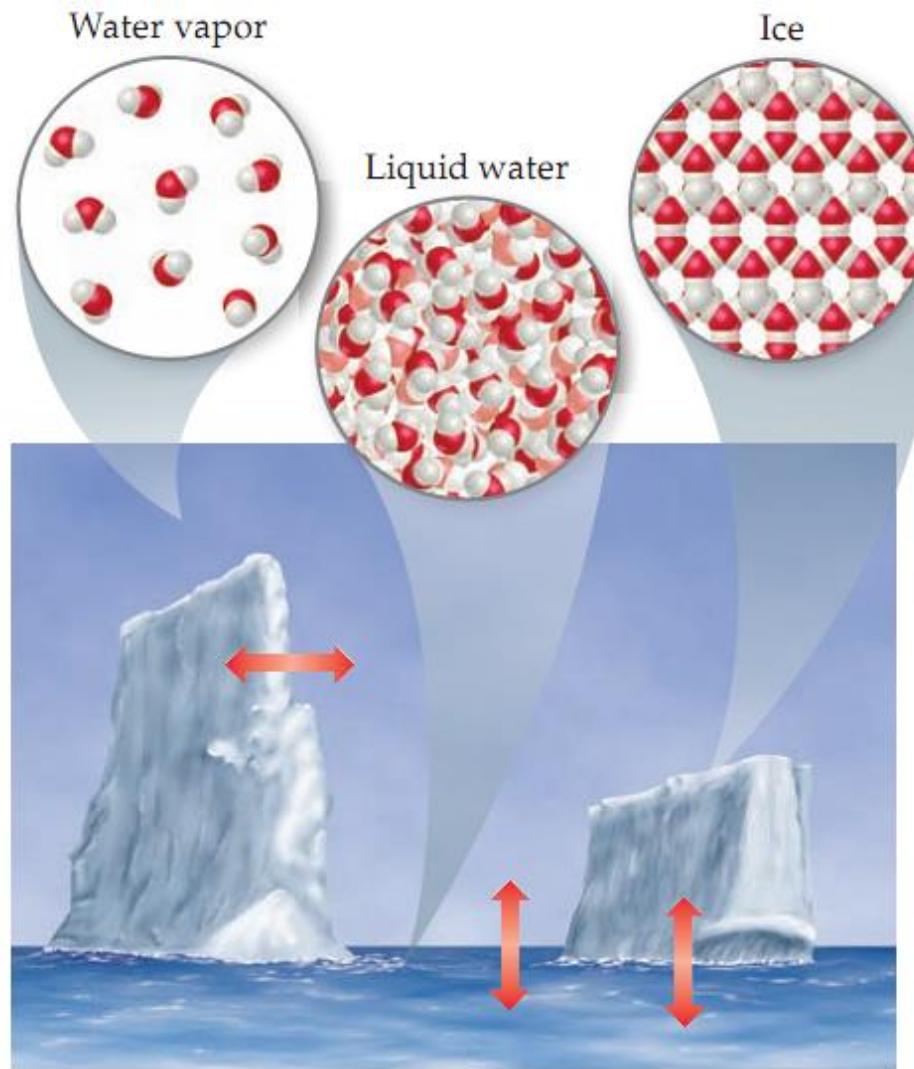
Homonuclear molecule



Compound



1-2 Classification of Matter

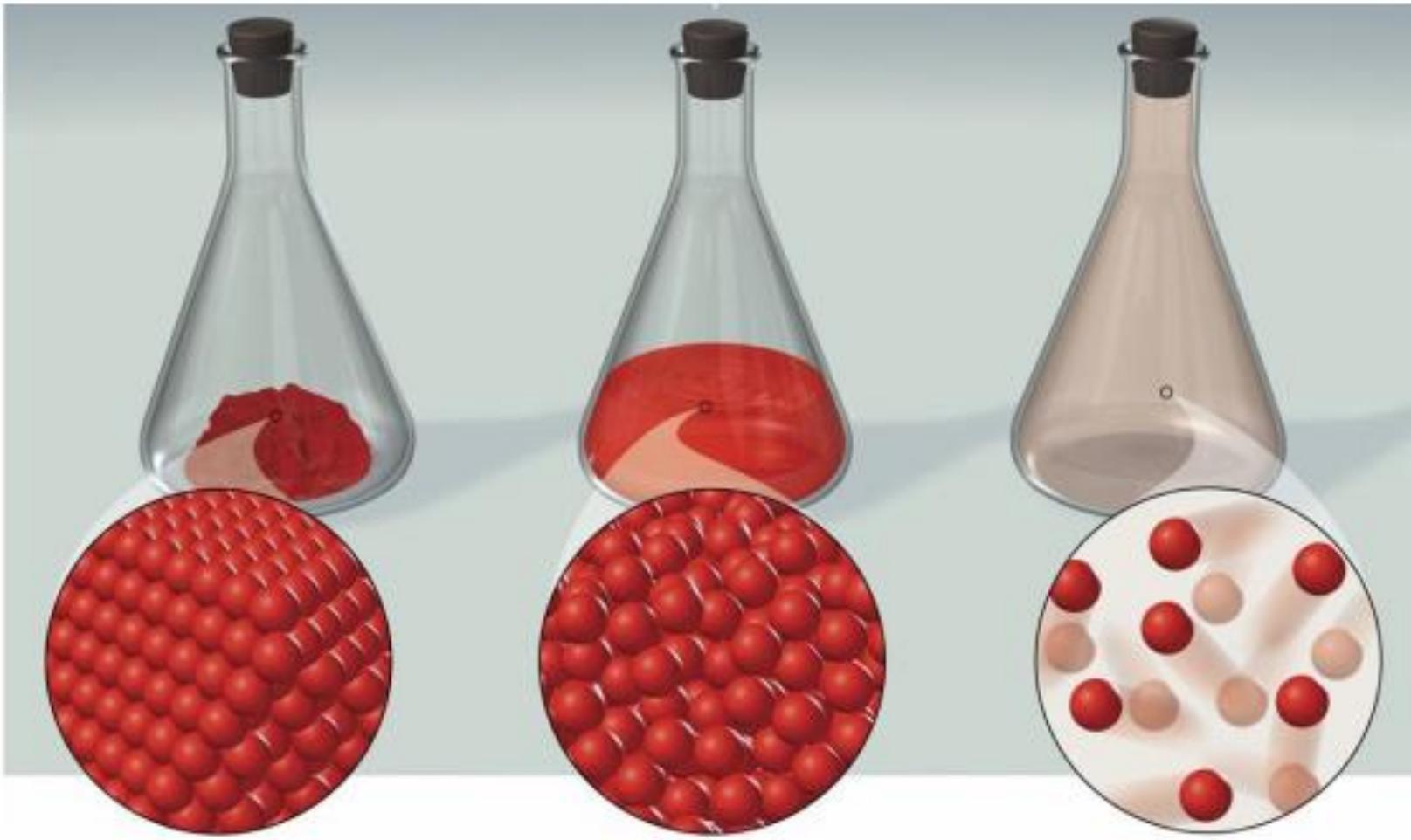


In which state of matter (gas, liquid or solid) are individual molecular furthest apart?

In which one they are the second furthest apart?

In which state are they closest together?

Physical States of Matter



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)

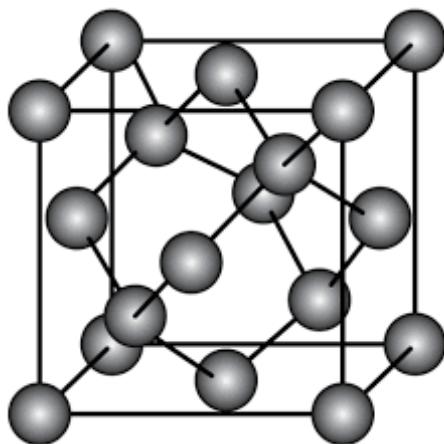
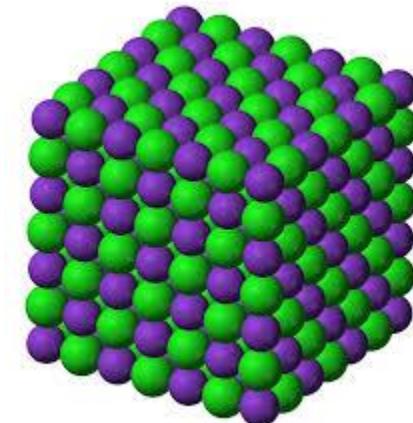


Table salt (sodium chloride, NaCl)



Mixtures

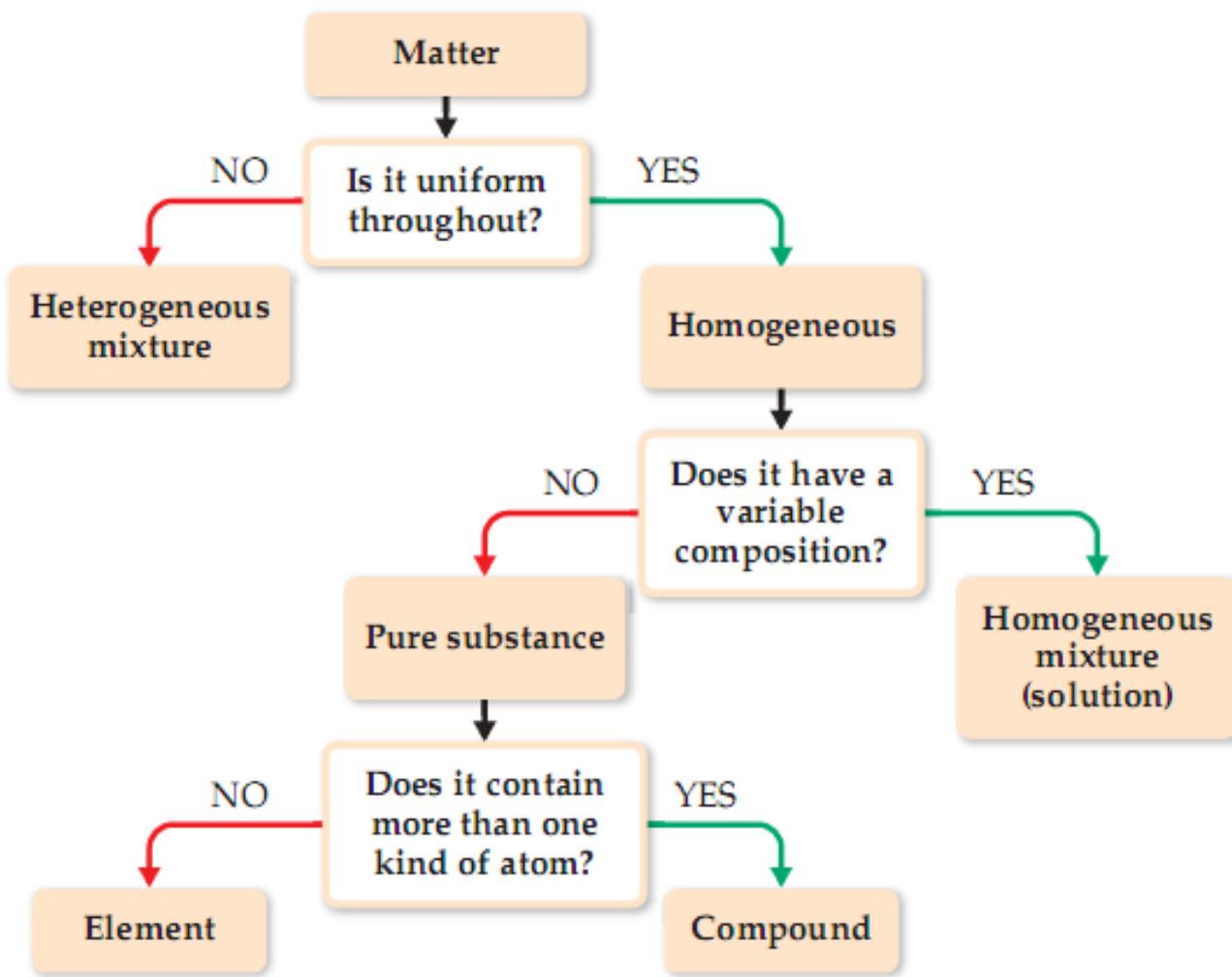
Mixture: collection of two or more pure substances



rocks
a heterogeneous mixtures

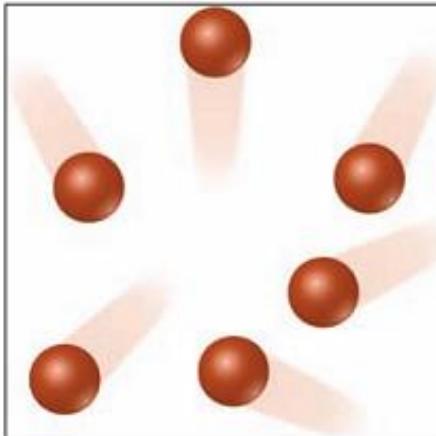


copper(II) sulfate aqueous solution
a homogeneous mixtures

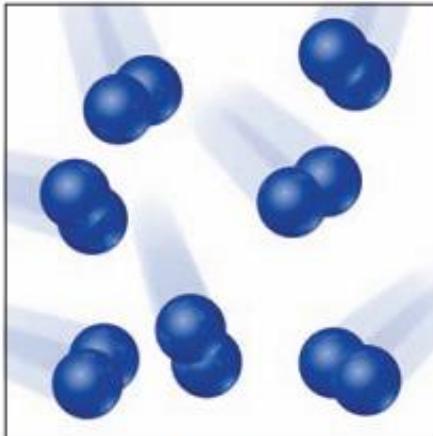


- **Matter** is made of atoms.
- **Atoms** are differentiated as **elements** (118 elements known).
- **Compounds** are comprised of two or more elements.
- **Molecules** are the smallest units of compounds.

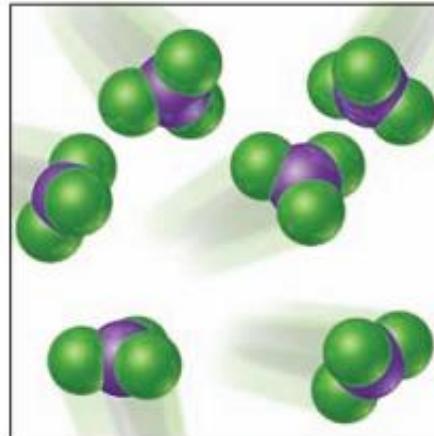
How do the molecules of a compound differ from the molecules of an element?



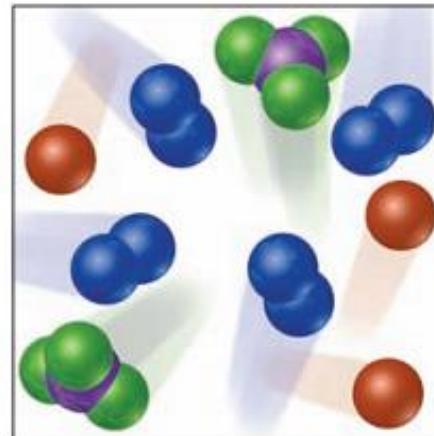
(a) Atoms of an element



(b) Molecules of an element



(c) Molecules of a compound



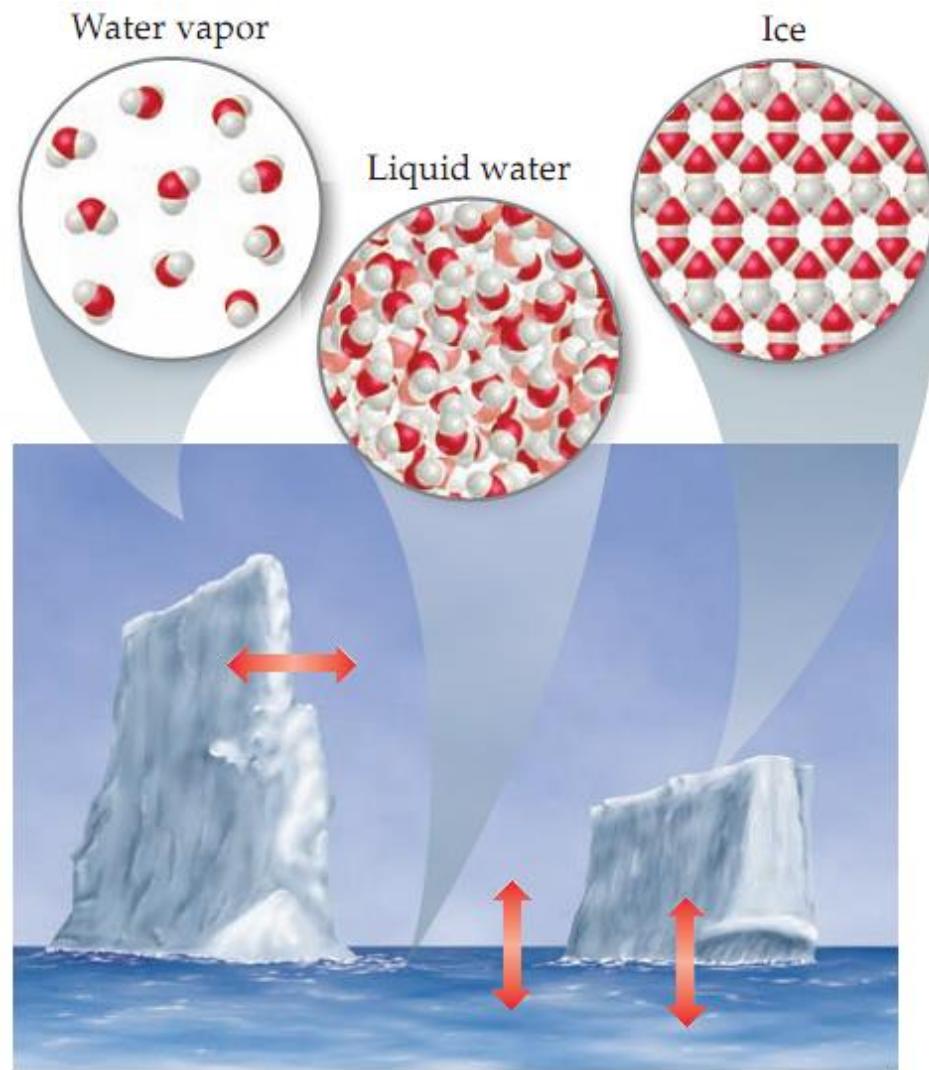
(d) Mixture of elements and a compound

Only one kind of atom is in any element.

Compounds must have at least two kinds of atoms.

1-3 Properties of Matter

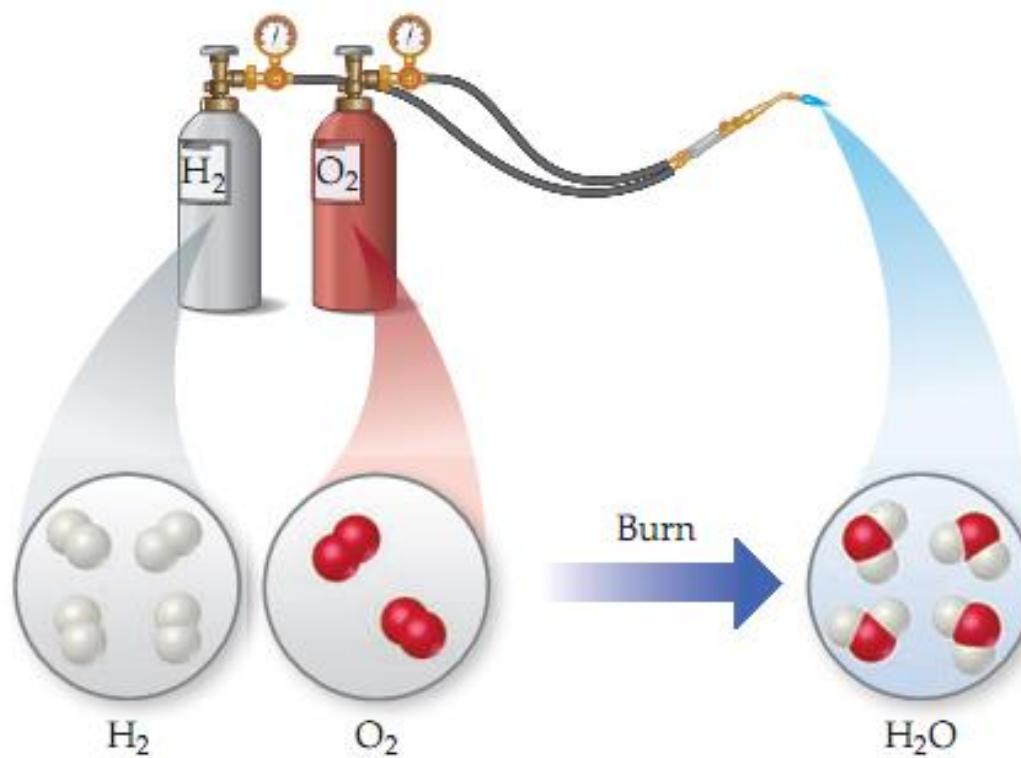
Physical
change



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



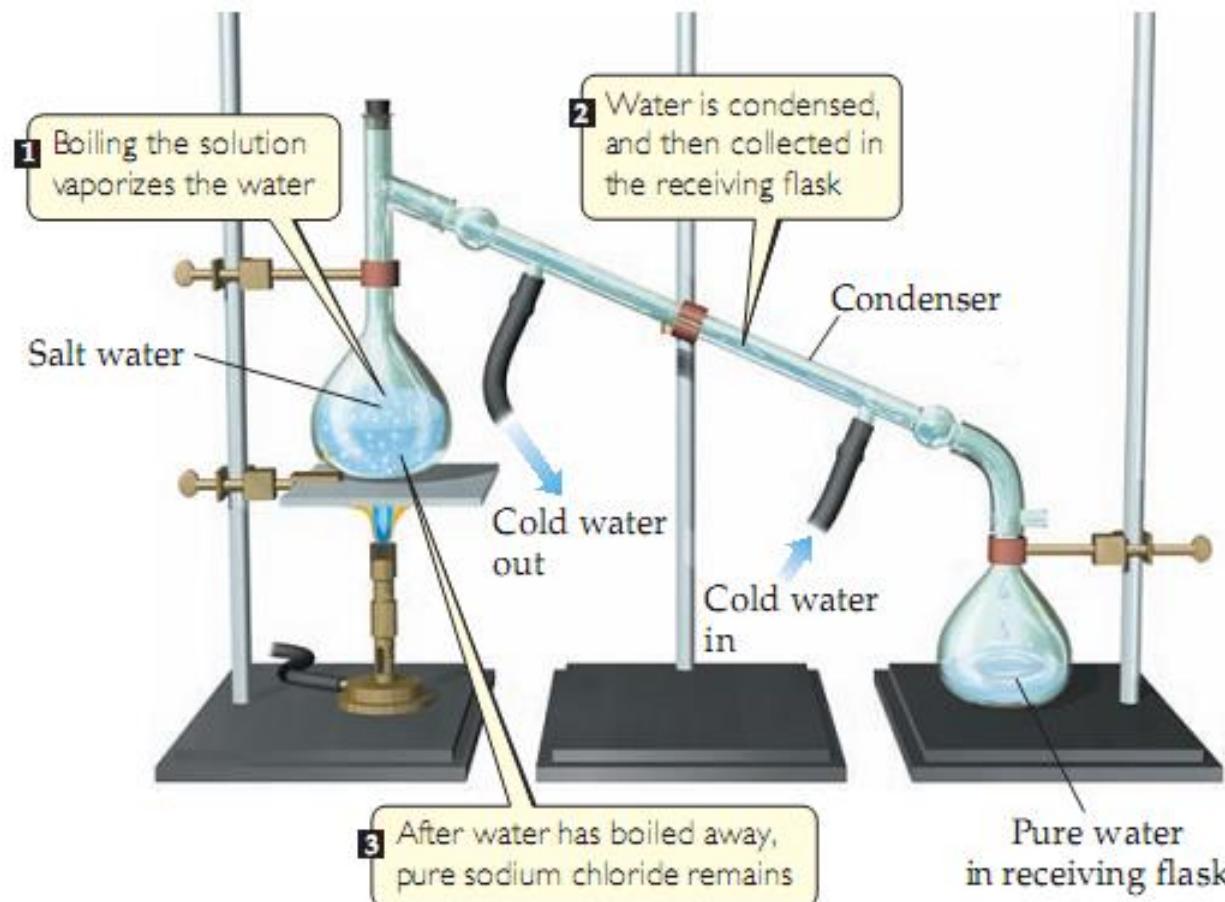
Chemical change – formation of a new compound (water)



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

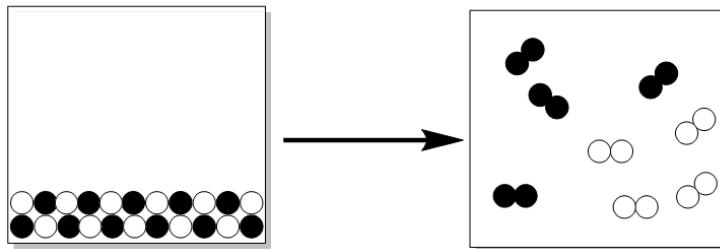
Which of the following represents a physical change?

- a. *Alkanes burn spontaneously.*
- b. *The sublimation of CO₂.*
- c. $2 H_2 (g) + O_2 (g) \rightarrow 2 H_2O (g)$
- d. *The rusting of a car.*

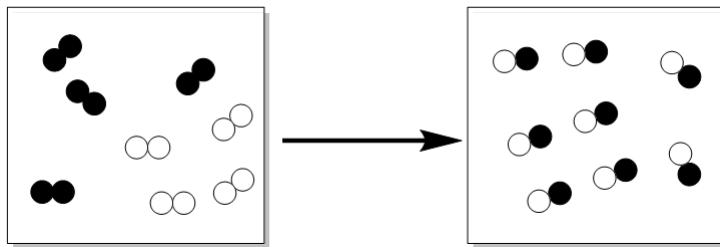
EXAMPLE

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

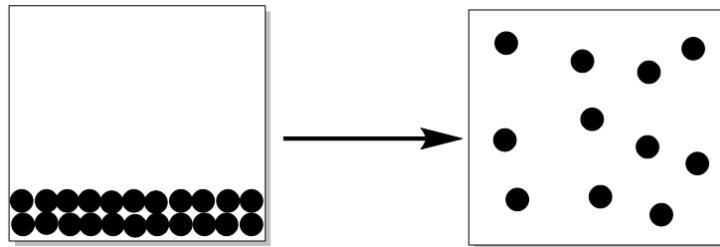
a.



b.

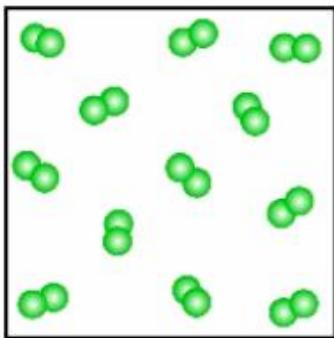


c.

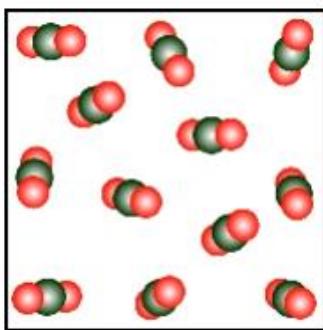


EXAMPLE

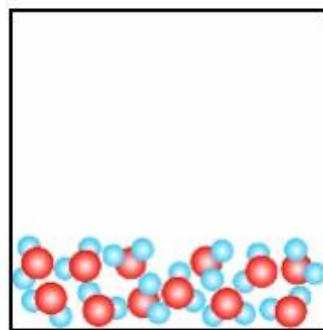
Answer each of the following questions based on the images provided below.



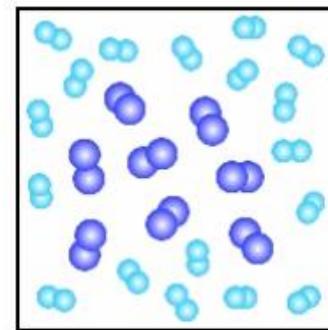
1



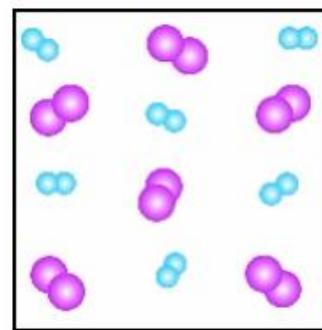
2



3



4



5

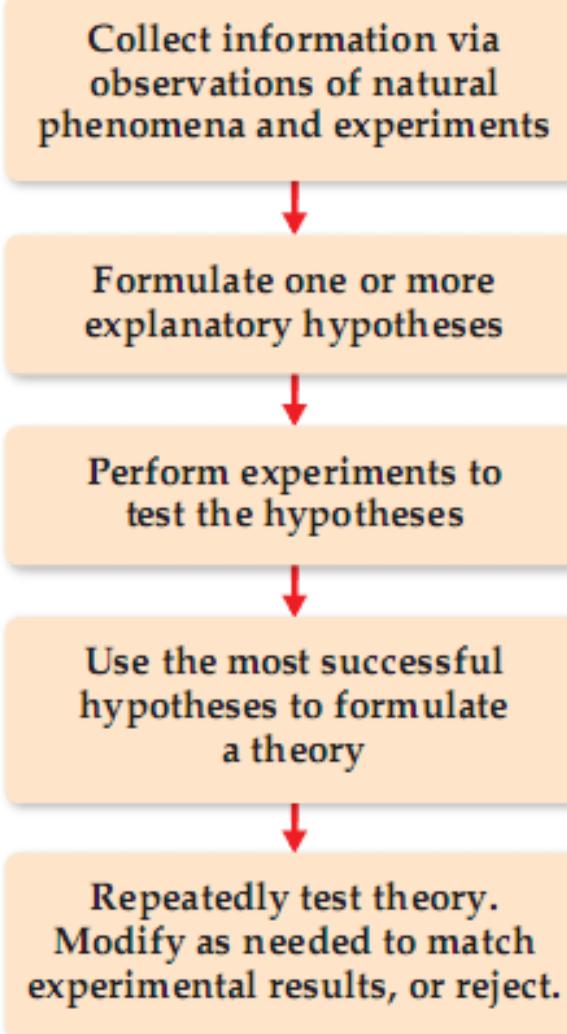
- a) Which images represents an elemental gas?
- b) Which images represents a heterogeneous mixture?
- c) Which images represents a liquid?

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 (μ W)	$= 1 \times 10^{-6}$ 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

$$6.88 \times 10^{-12}$$

digits power of ten

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

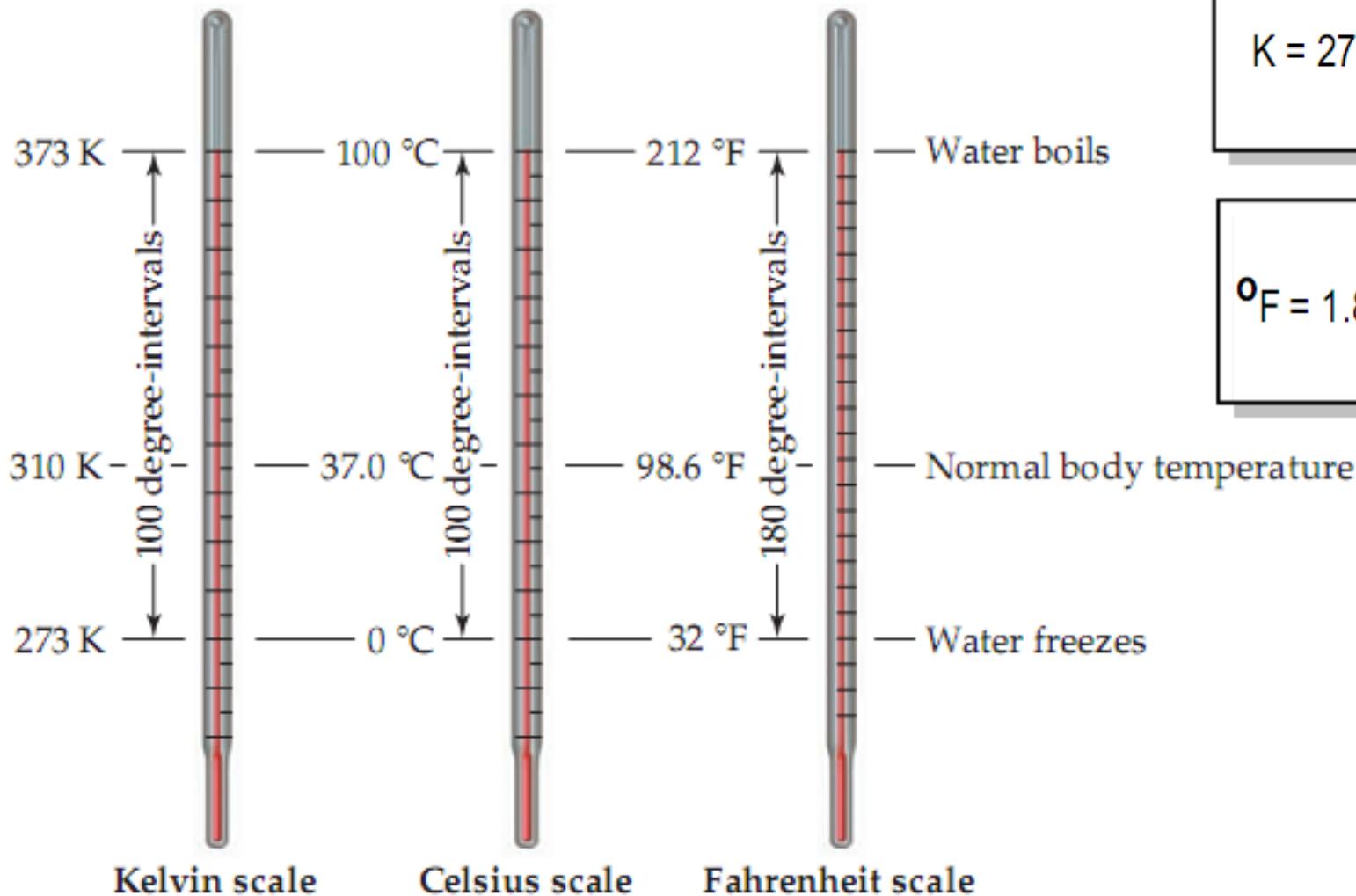
$$W \propto m$$

$$W = g \cdot m$$



Temperature

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



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

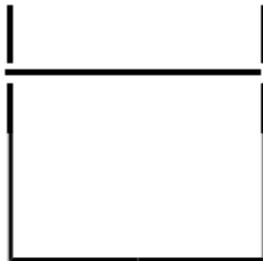
$${}^\circ F = 1.8 ({}^\circ C) + 32$$

- **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.

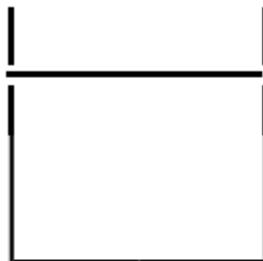


30 g H₂O at 50°C

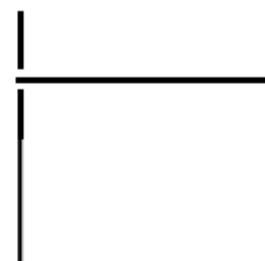


300 g H₂O at 50°C

b.

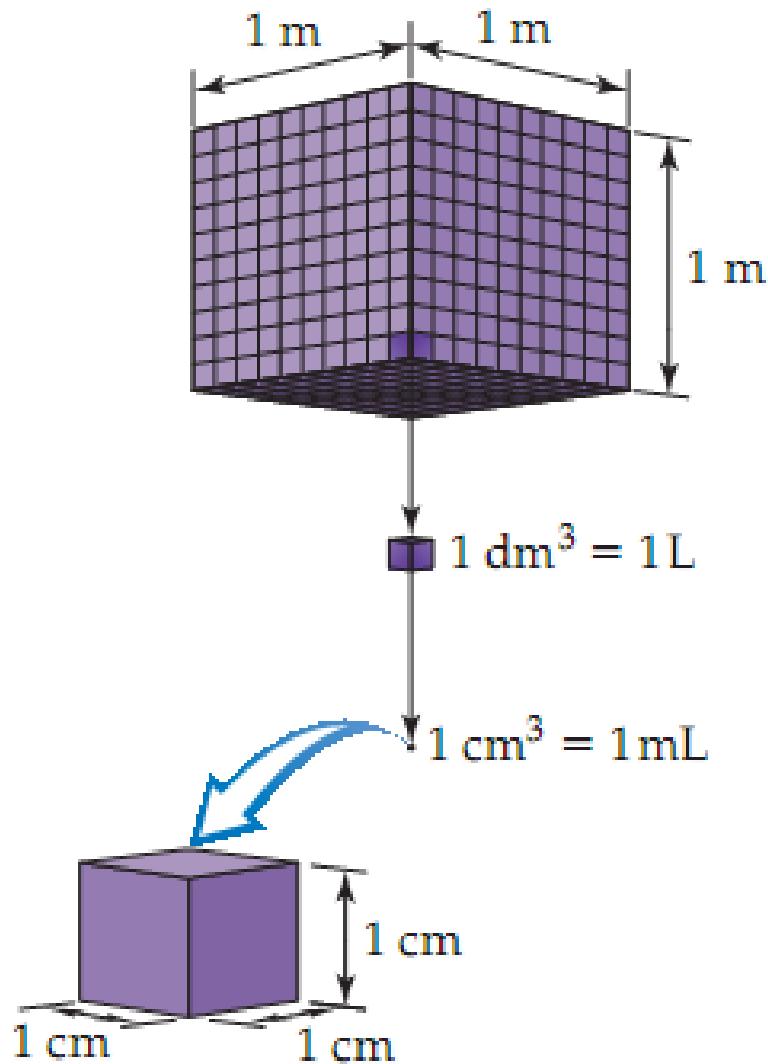


30 g H₂O at 50°C



30 g H₂O at 100°C

Volume

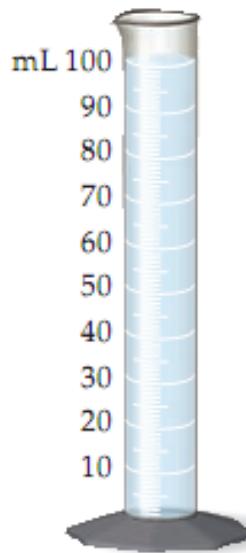


Density

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

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

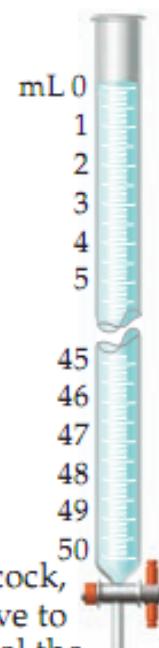
These deliver variable volumes



Graduated cylinder



Syringe



Stopcock,
a valve to
control the
liquid flow

Burette

Pipette delivers a specific volume



Pipette

Volumetric flask contains a specific volume



Volumetric flask

Common volumetric glassware for measuring volume of liquids

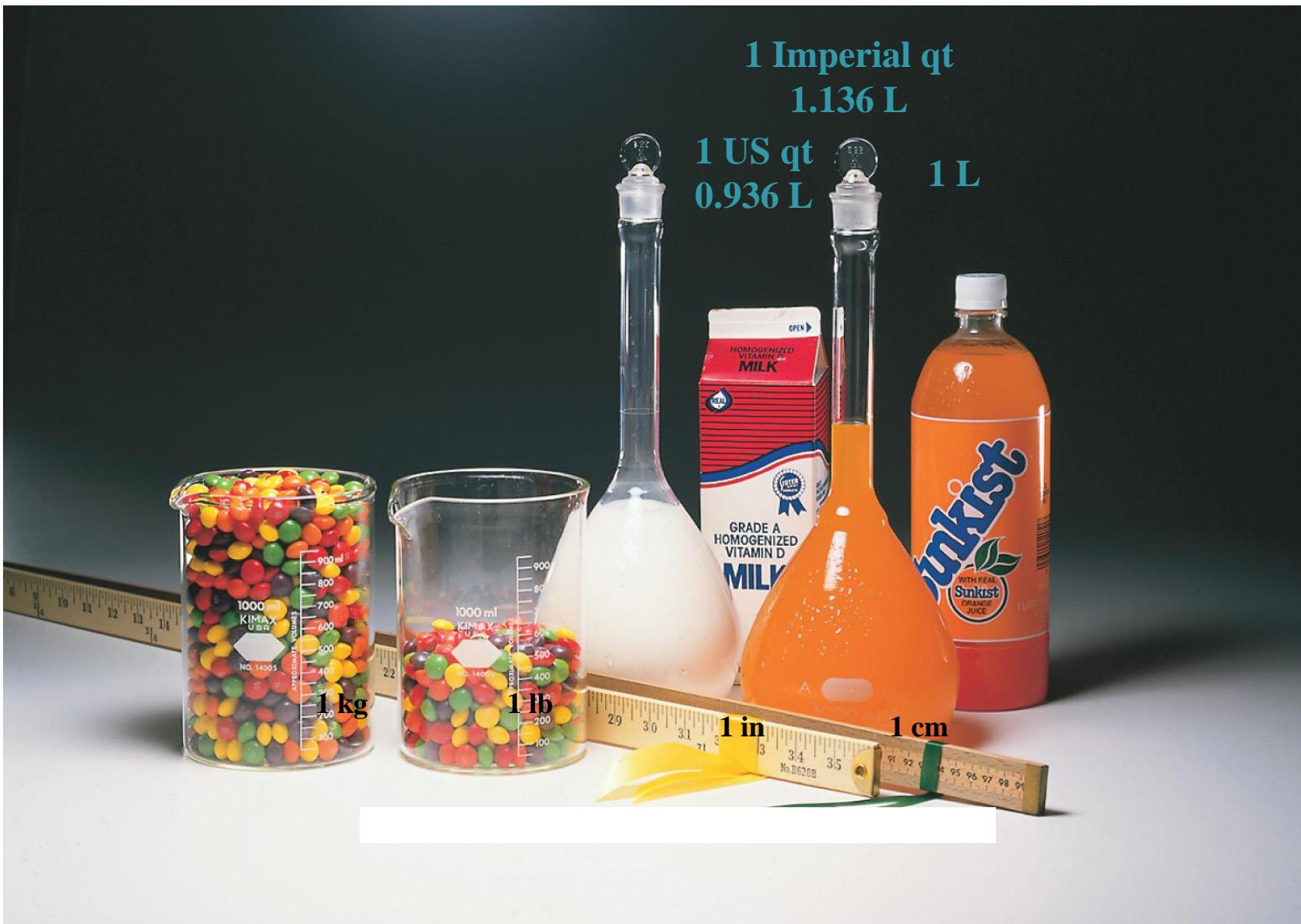
SI and non-SI Units Compared

1 Imperial qt

1.136 L

1 US qt
0.936 L

1 L



Units

S.I. Units

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

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 = $1.064 \times 10^2 \text{ kPa}$
	1 Atm = 760 mm Hg

Derived Quantities

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

Density and Percent Composition

$$\delta = m/V$$

$$m = V\delta$$

$$V = m/\delta$$

$$g/mL$$

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?

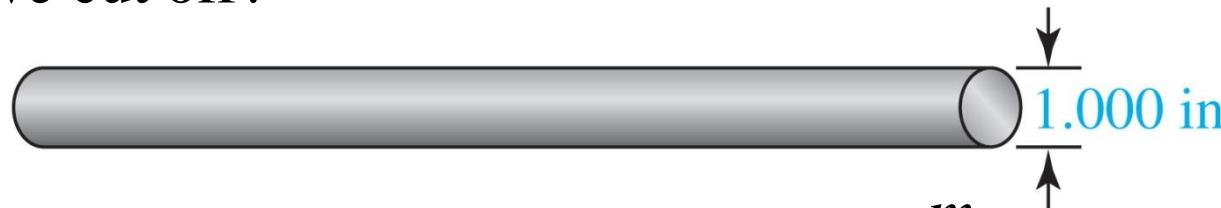
Have volume, need density = 22.48 g/cm^3

$$\begin{array}{c} \text{(converts in. to cm)} & \text{(converts cm to } \text{cm}^3\text{)} & \text{(converts } \text{cm}^3\text{ to g osmium)} \\ \swarrow & \nearrow & \searrow \\ ? \text{ g osmium} = \left[1.25 \text{ in.} \times \frac{2.54 \text{ cm}}{1 \text{ in.}} \right]^3 \times \frac{22.48 \text{ g osmium}}{1 \text{ cm}^3} & = 719 \text{ g osmium} \end{array}$$

EXAMPLE

Relating Mass, Volume and Density

The stainless steel in the solid cylindrical rod pictured below has a density of 7.75 g/cm³. If we want a 1.00 kg mass of this rod, how long a section must we cut off?



Calculate the Volume needed

$$V = \frac{m}{d} = m \times \frac{1}{d}$$

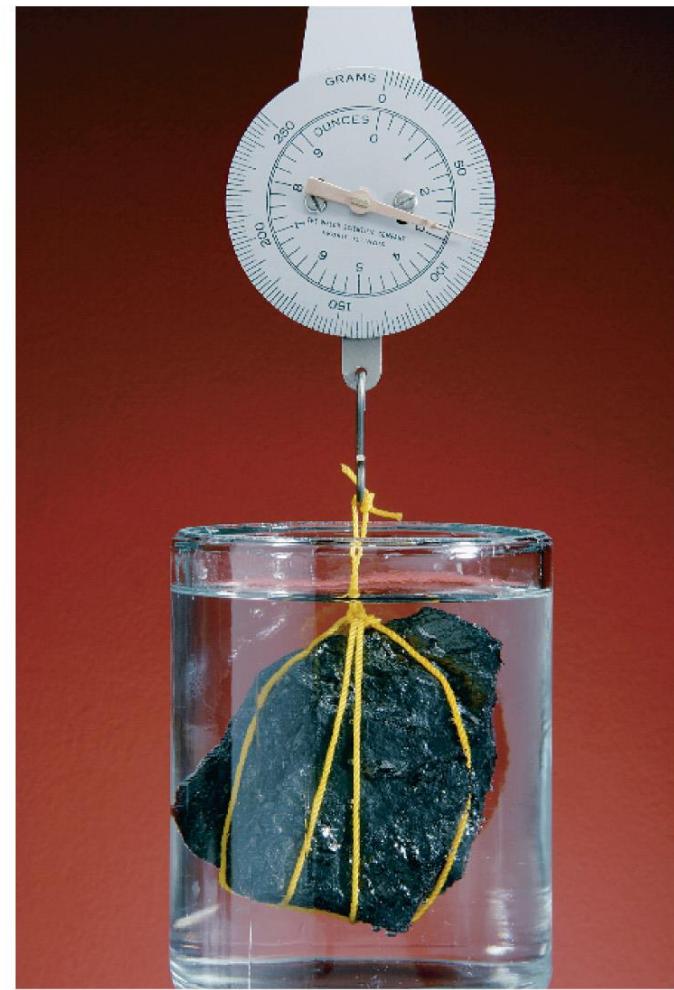
$$V = (1.00 \cancel{\text{kg}})(1000 \cancel{\text{g/kg}}) \times \frac{1 \cancel{\text{cm}}^3}{7.75 \cancel{\text{g}}} = 129 \text{ cm}^3$$

Calculate the Length

$$V = h \pi r^2 \quad h = \frac{V}{\pi r^2}$$

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

Measuring Volume of an Irregular Object



1-5 Uncertainty in Measurement



Good accuracy
Good 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.



Poor accuracy
Good precision



Poor accuracy
Poor precision

Precision



Reproducibility $\pm 0.1 \text{ g}$

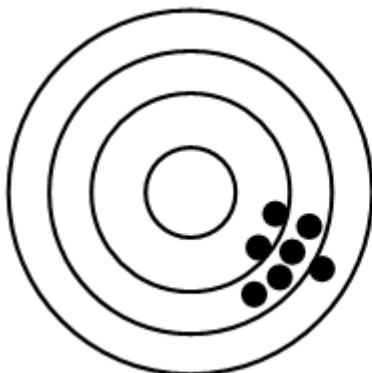
Precision low

$\pm 0.0001 \text{ g}$

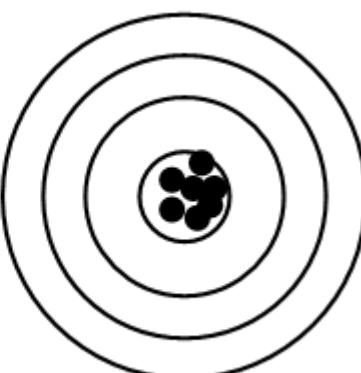
high

EXAMPLE

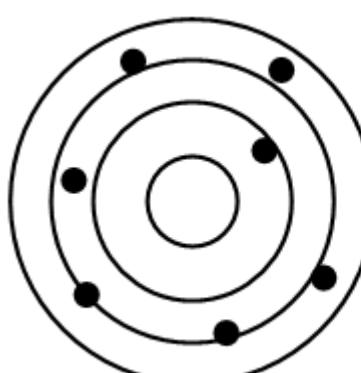
Which of the 4 following images is not precise and not accurate?



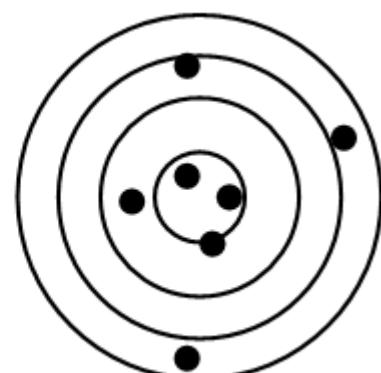
1



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.

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

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

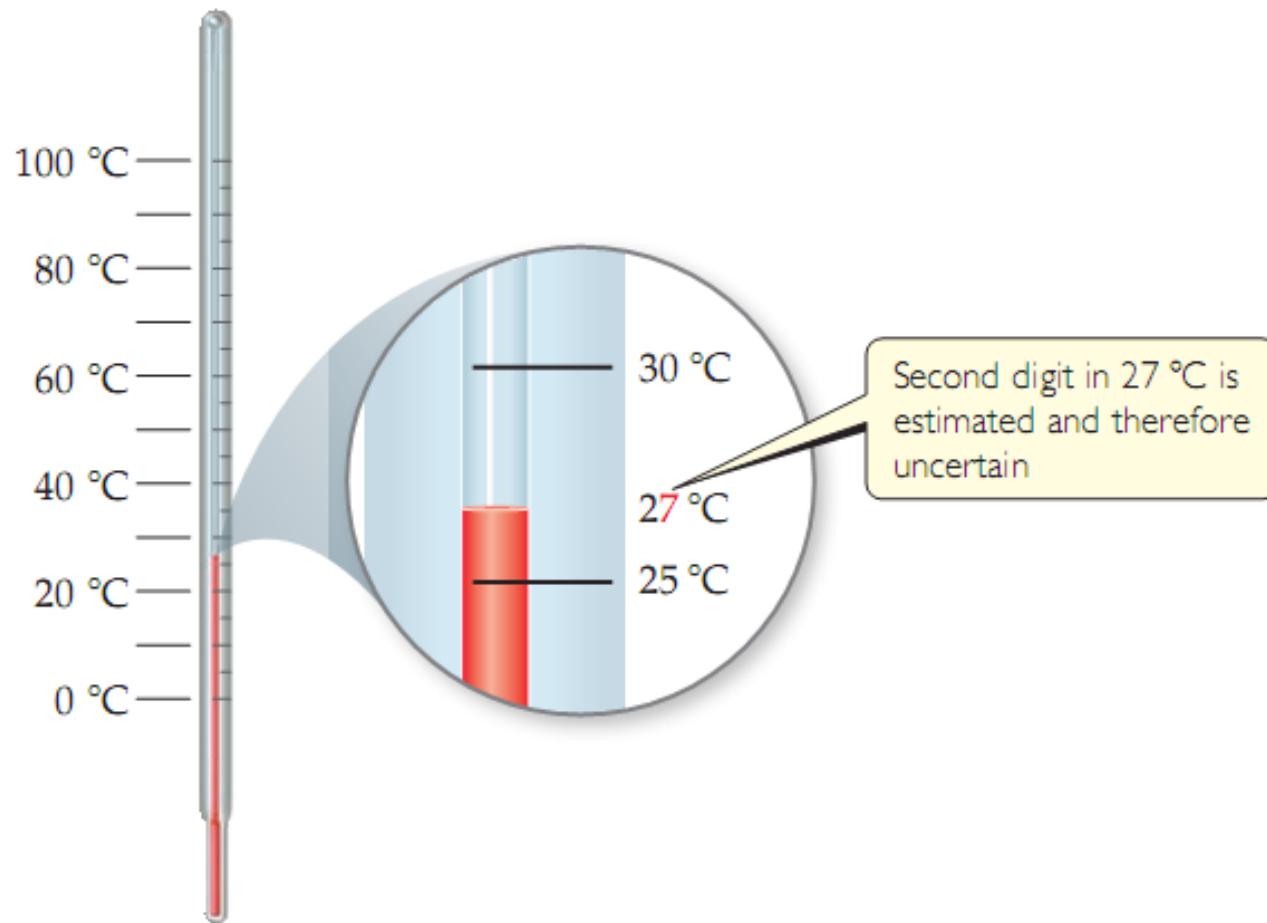
b. $0.39, 0.061,$ and 5.3×10^{-2}

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

Not significant:

zero for
“cosmetic”
purpose

0

.

Not significant:

zeros used only
to locate the
decimal point

0

0

4

0

0

4

5

0

0

Significant:

all nonzero
integers

Significant:

zeros at the end of
a number to the right
of decimal point

Significant:

all zeros between
nonzero numbers

EXAMPLE

How many sig figs does each number contain?

a. 0.0000185 m

b. 749 mol

c. $17.3 \times 10^3\text{ mL}$

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**

$$20.42 + 1.322 + 83.1 = 104.842$$

The diagram illustrates the decimal places for each term in the addition. The first term, 20.42, has two decimal places, indicated by a blue arrow pointing from the text "two decimal places" to the digit 2. The second term, 1.322, has three decimal places, indicated by a blue arrow pointing from the text "three decimal places" to the digit 2. The third term, 83.1, has one decimal place, indicated by a blue arrow pointing from the text "one decimal place" to the digit 1.

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**

$$\text{Area} = (6.221 \text{ cm})(5.2 \text{ cm}) = 32.3492 \text{ cm}^2 \Rightarrow \text{round off to } 32 \text{ cm}^2$$

four significant figures

two significant figures

We report the result as **32 cm²** 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. $(3.16) \times (0.003027) \times (5.7 \times 10^{-3})$

$$0.000054522324 = 5.\textcolor{red}{4}522324 \times 10^{-5} = \mathbf{5.5 \times 10^{-5}}$$

b.

$$\begin{array}{r} 2.628 \times 10^6 \\ 6.281 \times 10^4 \\ + \underline{0.827 \times 10^7} \\ \hline 10960180 = 1.0\textcolor{red}{9}60180 \times 10^7 = \mathbf{1.10 \times 10^7} \end{array}$$

EXAMPLE

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

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

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

2.628×10^6

b. 6.281×10^4

0.110×10^8

1.10×10^7

$+ 0.827 \times 10^7$

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.