MATTER and measurements

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Intended Learning Outcomes

- Identify matter and its classifications
- Convert units of measurements
- Solve problems related to volume, density and temperature

chemistry

- Concerned with matter and energy and their interaction with each other
- Foundation for other disciplines like:
  a. Engineering
  b. Health sciences
  c. Pharmacy and pharmacology

MATTER

- Anything that occupies space and has mass and occupies space
- Phases

  a. Solids (Fixed volume and shape)

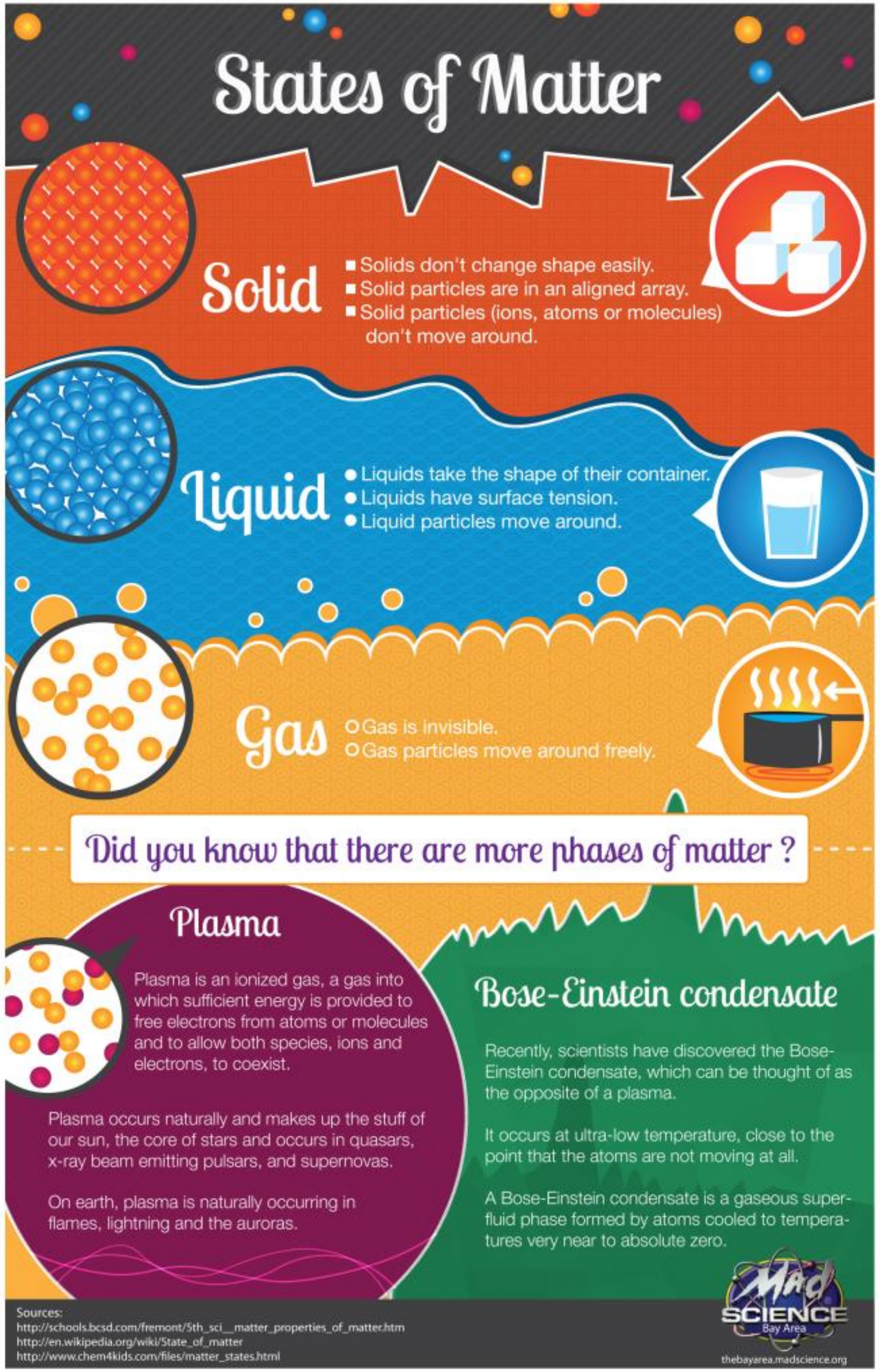
  b. Liquids (Fixed volume, indefinite shape)

  c. Gases (Indefinite shape and volume)

  d. Plasmas (no fixed shape or volume)

  e. Bose-Einstein Condensates (group of atoms cooled close to absolute zero)

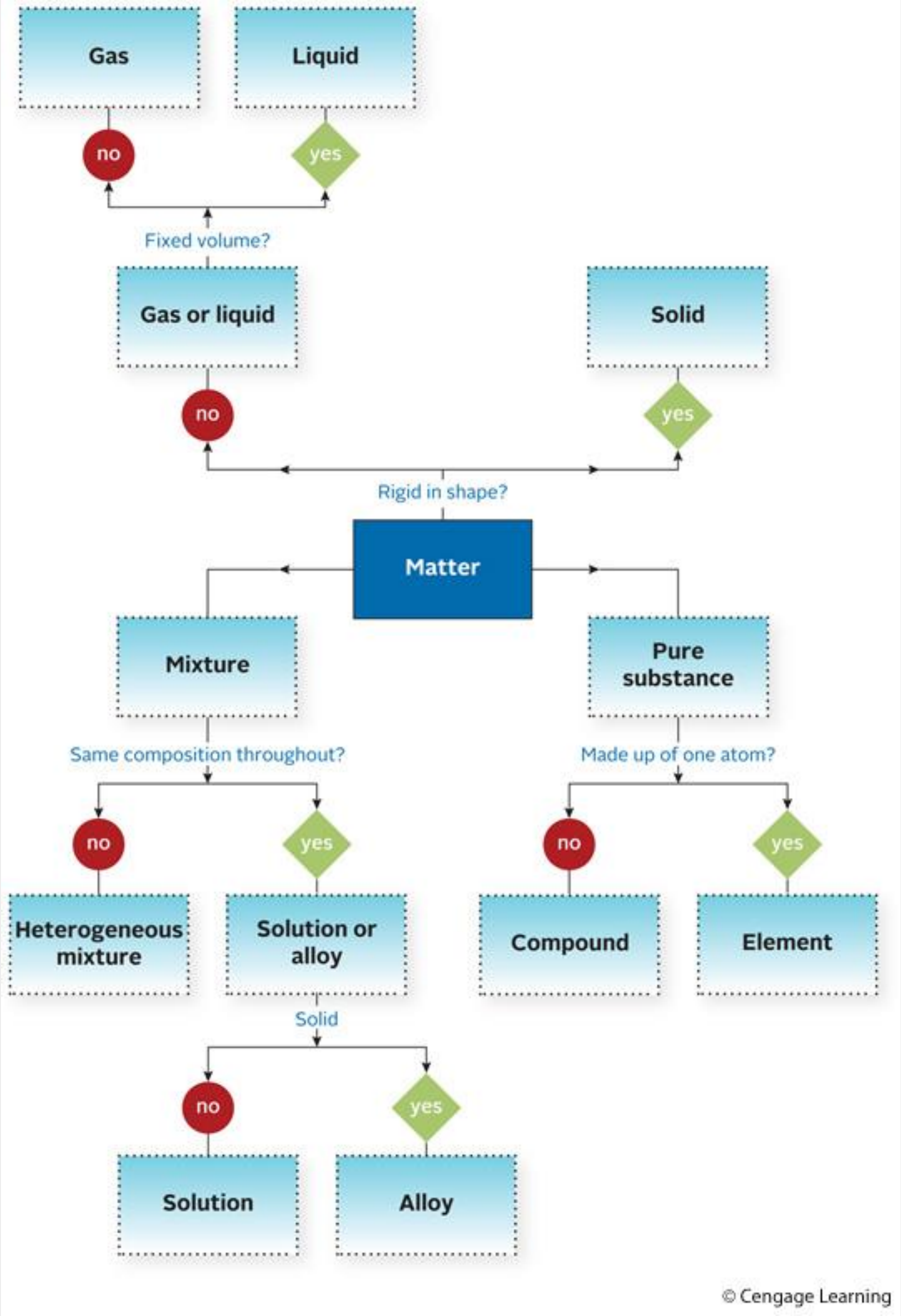
MATTER


States of Matter
Solid
Solids don't change shape easily.
Solid particles are in an aligned array.
Solid particles (ions, atoms or molecules) don't move around.
Liquid
Liquids take the shape of their container.
Liquids have surface tension.
Liquid particles move around.
Gas
Gas is invisible.
Gas particles move around freely.
Did you know that there are more phases of matter ?
Plasma
Plasma is an ionized gas, a gas into which sufficient energy is provided to free electrons from atoms or molecules and to allow both species, ions and electrons, to coexist.
Plasma occurs naturally and makes up the stuff of our sun, the core of stars and occurs in quasars, x-ray beam emitting pulsars, and supernovas.
On earth, plasma is naturally occurring in flames, lightning and the auroras.
Bose-Einstein condensate
Recently, scientists have discovered the Bose-Einstein condensate, which can be thought of as the opposite of a plasma.
It occurs at ultra-low temperature, close to the point that the atoms are not moving at all.
A Bose-Einstein condensate is a gaseous super-fluid phase formed by atoms cooled to tempera-tures very near to absolute zero.
Sources:
http://schools.bcsd.com/fremont/5th_sci__matter_properties_of_matter.htm
http://en.wikipedia.org/wiki/State_of_matter
http://www.chem4kids.com/files/matter_states.html
Mad SCIENCE Bay Area
thebayarea.madscience.org

MATTER & its classification

- Pure substances
  a. Fixed composition
  b. Unique set of properties
  c. Either elements or compounds
- Mixtures
  a. Consist of two or more substances
  b. Either homogenous or heterogenous

classification



elements

- Matter which cannot be broken down into two or more pure substances
- 118 elements, 91 occur naturally
- Common elements
  a. Carbon (found in charcoal)
  b. Copper (found in pipes, jewelry, etc.)
  c. Aluminum (used in household utensils)

- Element in and out fashion
  d. Silicon (used in multibillion-dollar semiconductors)
  e. Lead (banned in the U.S. due to its toxicity)

ATOMIC SYMBOLS

- Elements are given symbols
- Chemical identifier
- Usually derived from one or two letters of the name of the element
- Occasionally symbols are based from Latin names
    a. Copper, Cu (Cuprum)
    b. Mercury, Hg (Hydrargyrum)

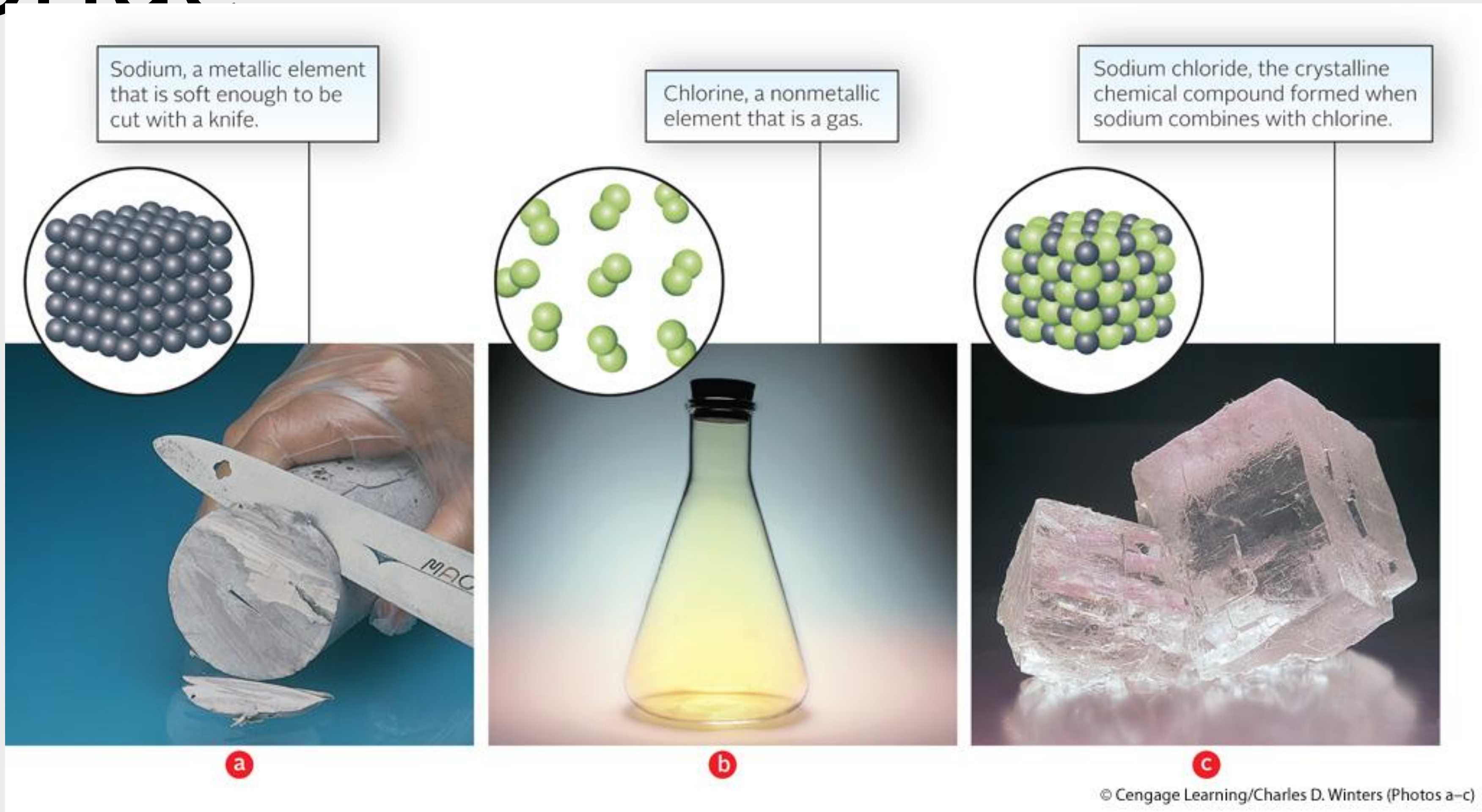
COMPOUNDS

- Pure substances containing a combination of two or more elements
- Hydrocarbons - Compounds containing carbon and hydrogen (Methane, acetylene, and naphthalene)
- Fixed composition

Composition of COMPOUNDS

- Compounds always contain the same elements in the same composition by mass
  - Water by mass
    - 11.19% hydrogen
    - 88.81% oxygen
- Properties of compounds are different from the properties of the elements from which they are formed
  - Table salt consists of
    - Sodium(Na) - Extremely reactive metal
    - Chlorine(Cl) - Poisonous, greenish-yellow gas

Sodium, chlorine, & sodium chloride



mixtures

- Two or more substances in such a combination that each substance retains its own chemical identity

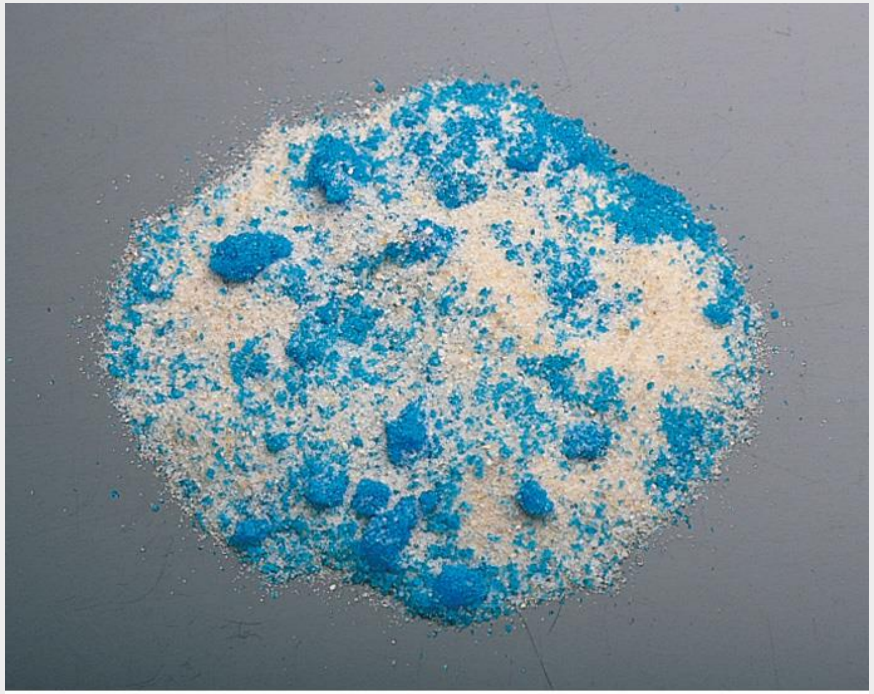
Example:

a. Copper sulfate and sand

- Identity of each is retained

*Contrast with the formation of a compound

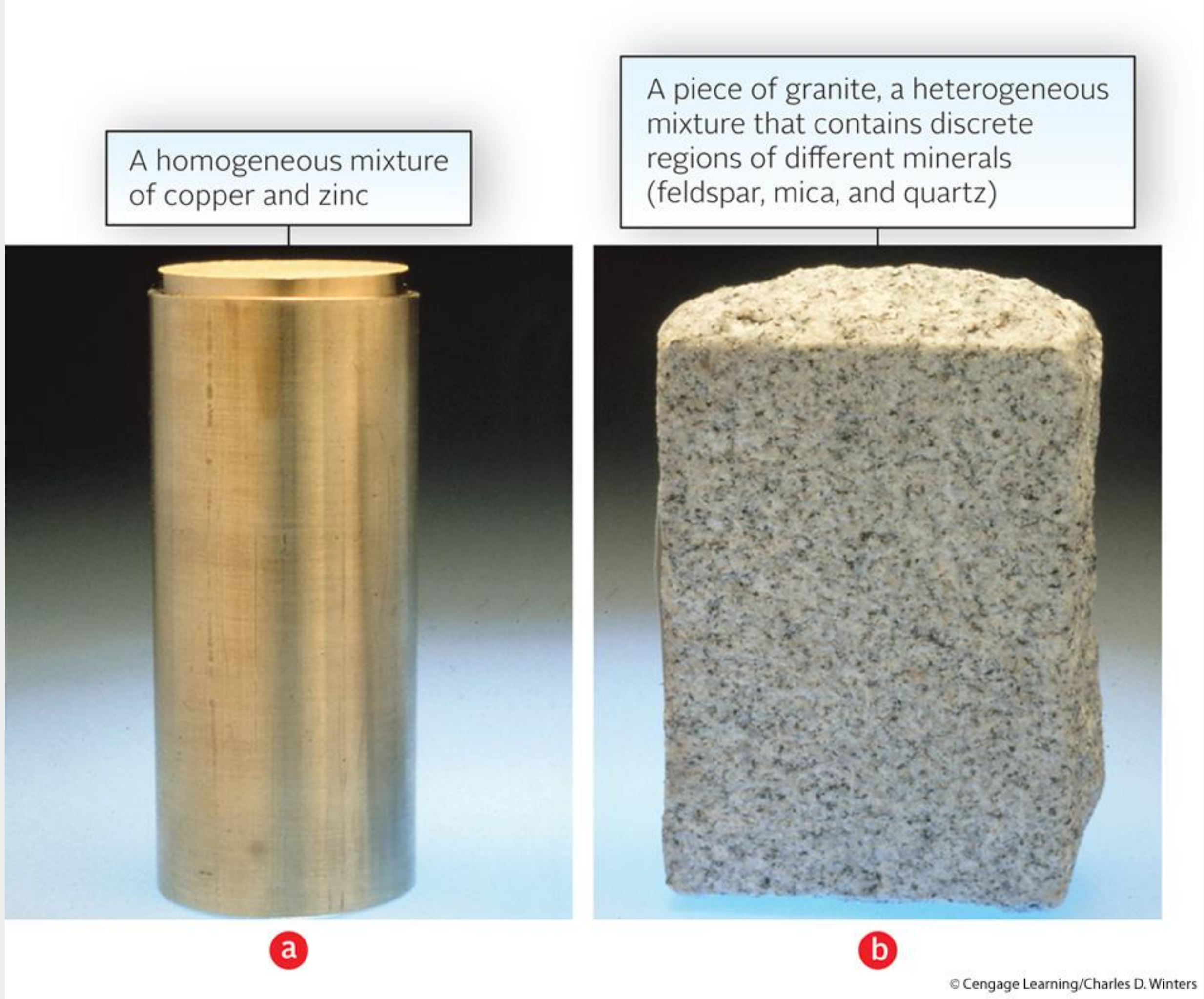
- Sodium and chlorine form sodium chloride



TYPES OF mixtures

- HOMOGENOUS MIXTURE
  - Also known as a solution
  - Uniform - Composition is the same throughout
  - Example – Seawater

- HETEROGENOUS MIXTURE
  - Nonuniform - Composition varies throughout
  - Example - Rocks



SOLUTIONS

- Common homogenous mixture
- Components:
  - Solvent – Substance present in larger amount (commonly liquid)
  - Solute – may be solid, liquid, or gas

Example – Seawater (Water is the solvent; Solutes may be one of a variety of salts)

Methods of separating mixtures

- Filtration: Used to separate a heterogeneous solid-liquid mixture

  - Pass the mixture through a barrier with fine pores (filter paper)

  *In the filtration of water-soluble copper sulfate and sand, the filter paper will hold back sand and allow the copper sulfate solution to pass through

- Distillation - Resolves homogeneous solid-liquid mixtures

  - Liquid vaporizes, leaving solid residue

  *Can be used in the separation of a copper sulfate water solution

measurements

- Chemistry is a quantitative science
- Experiments and calculations involve measured quantities that have a specific numerical value
- Scientific measurements are always expressed in the metric system
  - Decimal-based
  - Units of a particular quantity are related to each other by powers of ten

Metric prefixes

Factor	Prefix	Abbreviation	Factor	Prefix	Abbreviation
10^6	mega	M	10^{-3}	**milli**	m
10^3	**kilo**	k	10^{-6}	micro	μ
10^{-1}	deci	d	10^{-9}	**nano**	n
10^{-2}	**centi**	c	10^{-12}	pico	p

UniTS: LENGTH

- Standard unit is meter (m)
  - Meter is slightly longer than a yard
  - Now defined as the distance light travels in vacuum in 1/299,792,458 of a second
- Other units
  - Centimeter (1 cm $=10^{-2}$ m)
  - Millimeter (1 mm $= 10^{-3}$ m)
  - Kilometer (1 km $= 10^{3}$ m)
  - Nanometer (1 nm $= 10^{-9}$ m)

UniTS: volume

- Expressed in
  - Cubic centimeters
    - $1\ cm^3 = (10^{-2}\ m)^3 = 10^{-6}\ m^3$
  - Liters (L)
    - $1\ L = 10^{-3}\ m^3 = 10^3\ cm^3$
  - Milliliters (mL)
    - $1 mL = 10^{-3}\ L = 10^{-6}\ m^3$
    - Also, $1\ mL = 1\ cm^3$
- Measuring volume
  - Commonly used device - Graduated cylinder
  - Pipet or buret
    - Used when greater accuracy is required

UniTS: mass

- Expressed in
  - Grams (1 g = 10^{-3} kg)
  - Kilograms
  - Milligrams (1 mg = 10^{-3} g)
  - Metric ton or megagram (1 Mg = 10^6 g = 10^3 kg)
- Mass and weight
  - Mass - Measure of the amount of matter in an object
  - Weight - Gravitational force that acts on an object

UniTS: TEMPERATURE

- Factor that determines the direction of heat flow
- When there is a contact between two objects with different temperatures:
    - Heat flows from the object with the higher temperature to the one with the lower temperature
- Units
    - Celsius
    - Fahrenheit
    - Kelvin

Celsius and Fahrenheit scale

- Celsius scale
  - Water freezes at 0° C
  - Water boils at 100° C
- Fahrenheit scale
  - Water freezes at 32° F
  - Water boils at 212° F
- Comparing scales
  - 0° C is 32° F
  - 100° C is 212° F
  - There are 180° F for 100° C, so each °C is 1.8 times larger than each °F

KELVIN SCALE

- Kelvin: 1/273.16 of the difference between the lowest attainable temperature (0 K) and the triple point of water (0.01°C)
  - Unlike the other two scales, no degree sign is used to express temperature in K

RELATIONSHIPS BETWEEN TEMPERATURE SCALES

- Fahrenheit and Celsius scale

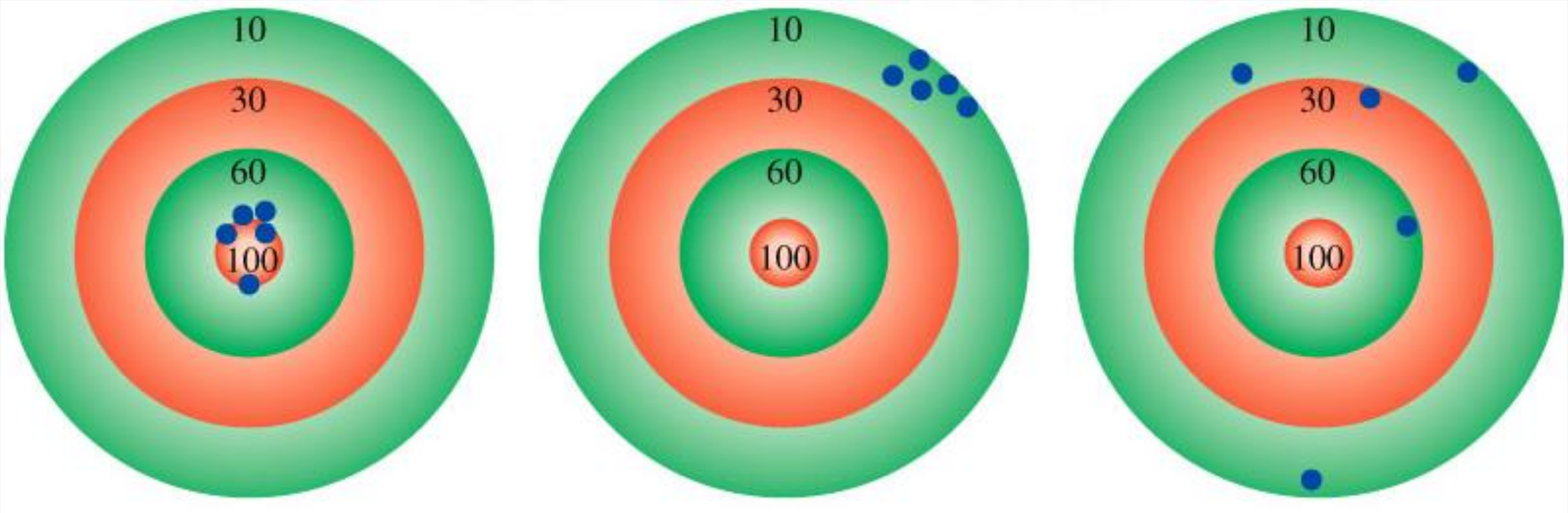
$$t_{^\circ F} = 1.8 t_{^\circ C} + 32^\circ$$

- Celsius and Kelvin scale

$$T_K = t_{^\circ C} + 273.15$$

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

Example 1.1

Mercury thermometers have been phased out because of the toxicity of mercury vapour. A common replacement for mercury in glass thermometers is the organic liquid isoamyl benzoate, which boils at 262° C. What is its boiling point in

(a) °F

(b) K

Solution:

(a)°F

$$t_{°F} = 1.8t_{°C} + 32^{\circ}$$

°F = 1.8(°C) + 32

= 1.8 (262 °C) + 32

$\boxed{= 504\ °F}$

(b) K

$$T_K = t_{°C} + 273.15$$

K = 262° C + 273.15

$\boxed{= 535\ K}$

Example 1.2

At what temperature are Celsius and Fahrenheit the same?

Solution: °F = 1.8(°C) + 32

Let: x = °F = °C

$$x = 1.8(x) + 32$$

$$x - 1.8(x) = 32$$

$$-0.8(x) = 32$$

$$\frac{-0.8x}{-0.8} = \frac{32}{-0.8}$$

$$\mathrm{x} = -40$$

$\boxed{\text{-40 °F = -40 °C}}$

RELATIONS BETWEEN LENGTH, VOLUME, AND MASS UNITS

Metric		English		Metric-English	
Length					
1 km	$= 10^3$ m	1 ft	= 12 in	1 in	= 2.54 cm*
1 cm	$= 10^{-2}$ m	1 yd	= 3 ft	1 m	= 39.37 in
1 mm	$= 10^{-3}$ m	1 mi	= 5280 ft	1 mi	= 1.609 km
1 nm	$= 10^{-9}$ m = 10 Å				
Volume					
1 m^3	$= 10^6$ cm^3 $= 10^3$ L	1 gal	= 4 qt = 8 pt	1 ft^3	= 28.32 L
1 cm^3	= 1 mL $= 10^{-3}$ L	1 qt (U.S. liq)	= 57.75 in^3	1 L	= 1.057 qt (U.S. liq)
Mass					
1 kg	$= 10^3$ g	1 lb	= 16 oz	1 lb	= 453.6 g
1 mg	$= 10^{-3}$ g	1 short ton	= 2000 lb	1 g	= 0.03527 oz
1 metric ton	$= 10^3$ kg			1 metric ton	= 1.102 short ton

*This conversion factor is exact; the inch is defined to be exactly 2.54 cm. The other factors listed in this column are approximate, quoted to four significant figures. Additional digits are available if needed for very accurate calculations. For example, the pound is defined to be 453.59237 g.

CONVERTING UNITS

- Conversion factor approach is used to convert one set of units to another (also known as dimensional analysis)
  - Only the units change
  - Conversion factors are numerically equal to 1

  $1L = 1000\ cm^3$

$$\frac{1L}{1000\ cm^3} = \frac{1000\ cm^3}{1000\ cm^3} = 1$$

CHOOSING A CONVERSION FACTOR

- Choose a conversion factor that puts the initial units in the denominator
  - Initial units will cancel
  - Final units will appear in the numerator

$$\cancel{\text{Initial unit}} \times \frac{\text{Wanted unit}}{\cancel{\text{Initial unit}}} = \text{Wanted unit}$$

Dimensional Analysis Method of Solving Problems

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

given quantity x conversion factor = desired quantity

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

Dimensional Analysis Method of Solving Problems

How many mL are in 1.63 L?

Conversion Unit 1 L = 1000 mL

$$1.63\ \cancel{L} \times \frac{1000\ mL}{1\cancel{L}} = 1630\ mL$$

$$1.63\ L \times \frac{1L}{1000\ mL} = 0.001630 \frac{L^2}{mL}$$

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

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

Example 1.3

A red blood cell has a diameter of 7.5 μm (micrometers). What is the diameter of the cell in inches? (1 inch = 2.54 cm)

Strategy:

Follow the plan: μm → cm → inches

Solution:

7.5 μm in inches -

$$7.5\mu\text{m} \times \frac{1\times10^{-6}\text{m}}{1\mu\text{m}} \times \frac{100\text{ cm}}{1\text{m}} \times \frac{1\text{ in}}{2.54\text{ cm}} = 3.0\times10^{-4}\text{ in}$$

Example 1.4

The beds in your dorm room have extra-long mattresses. These mattresses are 80 inches (2 significant figures) long and 39 inches wide. (Regular twin beds are 72 inches long.) What is the area of the mattress top in m^2? (1 inch = 2.54 cm)

Strategy:

Recall equation for finding the area of a rectangle:

$$\text{area} = \text{length} \times \text{width}$$

Follow the plan

$$\text{in}^2 \rightarrow \text{cm}^2 \rightarrow \text{m}^2$$

Example 1.4

The beds in your dorm room have extra-long mattresses. These mattresses are 80 inches (2 significant figures) long and 39 inches wide. (Regular twin beds are 72 inches long.) What is the area of the mattress top in m^2? (1 inch = 2.54 cm)

Solution:

Area in in^2 - $80\,\text{in} \times 39\,\text{in} = 3.12\times10^3\ \text{in}^2$

(We will round off to correct significant figures at the end)

Area in m^2 -

$$3.12\times10^3\,\text{in}^2 \times \frac{(2.54)^2\,\text{cm}^2}{(1)^2\,\text{in}^2} \times \frac{(1)^2\,\text{m}^2}{(100)^2\,\text{cm}^2} = 2.0\ \text{m}^2$$

PROPERTIES OF SUBSTANCES

- Intensive properties: Independent of amount and used to identify substances
- Extensive properties: Dependent on amount
  - Mass and volume
- Fundamental properties of matter
  - Chemical properties
    - Observed during a chemical change that converts it into a new substance
  - Physical properties
    - Observed without making changes in the chemical identity of substances

PHYSICAL PROPERTIES

- Melting point: Temperature at which a solid changes to its liquid form
- Boiling point: Temperature at which vapor-filled bubbles form within a liquid

DENSITY

- Ratio of mass to volume

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

- Mass and volume are extensive properties, but the ratio of mass to volume is an intensive property
- Calculating density
  - Gases and liquids - Independently measure the mass and volume
  - Solids - Weigh the solid for mass, and volume is measured using the given dimensions

Example 1.5

Glycerol is a viscous liquid used by both the pharmaceutical and food industries as a sweetener, thickener, and stabilizer. To determine its density, a student delivers a 15.0 mL sample by pipet into a flask with a mass of 28.45 g. The mass of the flask and glycerol sample is 47.37 g. What is the density of glycerol?

Analysis:

Information given: Mass of empty flask (28.45 g)
Mass of flask + sample (47.37 g)
Volume of sample (15.0 mL)

Asked for: Density of the sample

Strategy:

1. Find the mass of the sample by difference

$$\text{mass of sample} = (\text{mass of flask} + \text{sample}) - (\text{mass of flask})$$

Example 1.5

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2. Recall the formula of density

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

Solution:

1. Mass of sample -

$$\text{mass of sample} = (\text{mass of flask} + \text{sample}) - (\text{mass of flask})$$

$$= 47.37\text{g} - 28.5\text{g} = 18.92\text{g}$$

2. Density -

$$d = \frac{\text{mass}}{V} = \frac{18.92\text{g}}{15.0\text{mL}} = 1.26 \text{ g/mL}$$

references

- Chang, R. (2010). *Chemistry*. Boston: McGraw-Hill Higher Education.
- Masterton,W.L, et al (2018) *Principles and Reactions: Chemistry for Engineering Students*, Cengage Learning

Thank you!

Any questions?

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