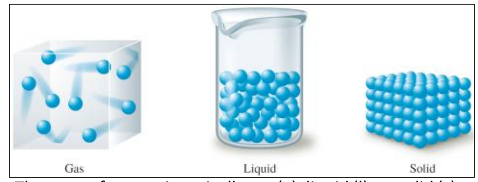
Lecture 2 Goals

- Slides covering McMurry Ch 1.2 – 1.10
  - Lots of background info you will use all semester!
  - This material will prepare you for Homework #1, due next Saturday
- The short list of (potential exam) topics to know:
  - 1.1* Physical vs. chemical change (see also 1.6*)
  - 1.2 Describe the states of matter (solid, liquid, gas) at the atomic scale
  - 1.3 Pure vs. mixture, homogeneous vs. heterogeneous, element vs. compound
  - 1.4 Memorize first 30 elements & symbols, plus Br, I, Ag, Au, Hg, Pb, Ba, Cd, Sn
  - 1.5 Find metals, nonmetals, and metalloids on the periodic table
  - 1.6* Understand the terms: (chemical) reaction, reactants, and products
  - 1.7 Know your standard units (g, cm, °C, etc.) and Metric prefixes (nano-kilo)
  - 1.8 Know the meaning of mass/weight, length, and volume
  - 1.9 Know how to count significant figures (sig figs or s.f.), especially whether or not to count any zeros. There is always one uncertain digit at the end.
  - 1.10* Practice scientific notation until you are good at it!!!

* You may need to self study Ch 1.1, 1.6, and 1.10, if we run out of time in lecture.

1.2 States of Matter



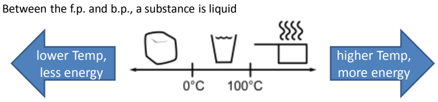
The state of matter is typically gas (g), liquid (l), or solid (s).

A change of state is always a physical change…
…because the chemical identify of the matter is not altered.

Example: Steam (g), water (l), and ice (s) are the same chemical species (H_2O) at different states. Each blue dot represents a water "molecule," the smallest indivisible unit of water.

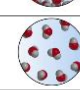
Why do different states exist?

- Temperature is the common explanation
  - Below its freezing point (f.p.), a substance is a solid
  - Above its boiling point (b.p.), a substance is a gas
  - Between the f.p. and b.p., a substance is liquid

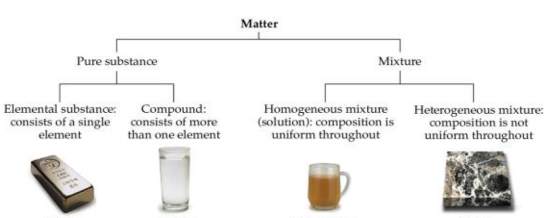


- In chemistry, temperature is a measure of energy
  - Higher Temp means more molecular kinetic (motion & vibration) energy
    - Solid molecules have the lowest energy and the least motion
      - Molecules are fixed in place and only vibrate
    - Liquid molecules have intermediate levels of energy and motion
      - Molecules move freely around each other (and also vibrate)
    - Gas molecules have the highest energy and the most motion
      - They fly about freely at high speed (and also vibrate)

Microscopic vs Macroscopic characteristics

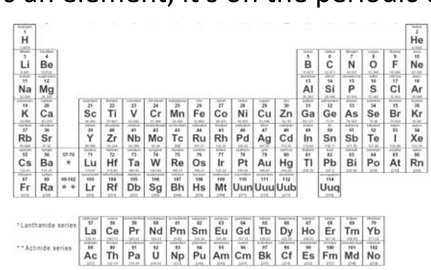
	Microscopic The atoms/molecules are…	They look like:	Macroscopic The bulk materials is…
solid	…touching and fixed into a rigid lattice (array).		…rigid, and has surfaces
liquid	…touching yet free to move about… No lattice.		… fluid (not rigid) to take shape of the container, and has a surface
gas	…flying around with large distances in between.		…fluid to completely fill container, without any surface.

1.3 Classification of Matter



Note that mixing is always a physical change.
Transformations among elements and compounds are chemical changes.

But what is an element???
If it's an element, it's on the periodic table.



Elements are listed on the periodic table. Compounds contain multiple elements.

Example: Hydrogen (H) and oxygen (O) are elements. Water is a compound with formula H_2O, representing a molecule with two hydrogen atoms and one oxygen atom.

Homo- (same) and *Hetero*- (different)

- Homogenous – same composition throughout
  - "well mixed" at the molecular level
  - Visibly uniform at the macroscopic level
  - Examples:
    - sugar dissolved in water
    - air (a mixture of pure oxygen, nitrogen, argon, etc.)
    - brass is an alloy (metal mixture) of elements copper and zinc

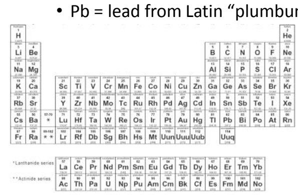
sugar water

- Heterogeneous – different/variable composition
  - "chunky" with patches of different composition
  - could pick apart into pure substances by hand
  - Examples:
    - sand stirred into water
    - soil

"sand water"

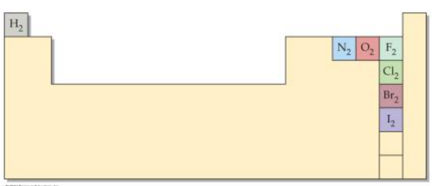
1.4 Elements and Symbols

- Each element has a unique symbol
  - 1 or 2 letters
    - First letter capitalized
    - Second letter lower case (if present)
- Some element symbols are derived from Latin
  - Au = gold for Latin "aurum" for aura or glow
  - Pb = lead from Latin "plumbum" used for (water) pipes



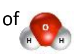
Things to Know

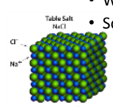
- Names of first 30 elements
  - plus Br, I, Ag, Au, Hg, Pb, Ba, Cd, Sn
- Which elements are <u>diatomic molecules</u>
  - Technically, the diatomics are <u>not</u> compounds
  - Recall that compounds have multiple elements

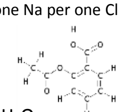


Chemical Formulas and Compounds

- Compound – substance composed of multiple elements
  - Compounds always have the same proportions of elements
    - Water (formula H_2O) is always two H per one O
    - Sodium chloride (NaCl, table salt) is always one Na per one Cl







  - "Big" compounds exist such as aspirin $C_9H_8O_4$

Aspirin $C_9H_8O_4$

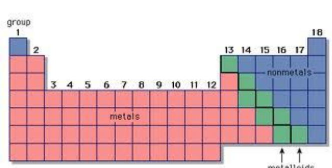
- Pure elements – just a single element
  - Mercury has the "formula" Hg

Mercury Hg

1.5 Elements and the Periodic Table

- Elements are roughly divided into 3 groups:
  - **Metals:** Found on the left side of the table
  - **Nonmetals:** Found on the right side of the table
  - **Metalloids:** Found along a diagonal trail between metals and nonmetals

Hydrogen is unique… it doesn't quite fit because the first row only has 2 elements.



Metals

- Most of the elements (94 of 118), left side of periodic table
- Solid at room temperature (except mercury, Hg)
- Conduct heat and electricity
- Lustrous (shiny)
- Malleable (bendable) and ductile

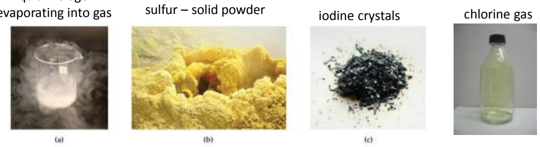
copper

(a) (b) (c)

Nonmetals

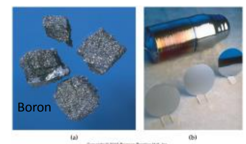
- Only 18 elements, right side of periodic table
- Tend to be gasses at room temperature
  - 11 gasses, 6 solids, 1 liquid
  - Insulators – poorly conduct heat and electricity
  - Brittle (easily cracked) when solid

liquid nitrogen evaporating into gas | sulfur – solid powder | iodine crystals | chlorine gas



Metalloids

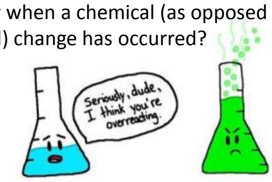
- 6 to 8 elements, depending on who's counting
- Properties intermediate of metals and nonmetals
- <u>Semiconductor</u> properties are important
  - Conductor/insulator properties change with applied voltage
  - Important for the electronics/hardware and emerging nanotechnology industries



silicon – manufactured as a thin "wafer"

1.6 Chemical Changes *[study at home]*

How do we know when a chemical (as opposed to physical) change has occurred?



A chemical change has occurred when the chemical composition of matter has changed… but you generally can't "see" the molecules!

You must infer when a chemical change has occurred.

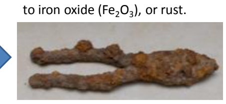
Heat, light, and/or electricity are generally absorbed or emitted when a chemical reaction occurs.

Chemical change examples

New (-ish) pliers made of iron (Fe)

chemical change

Very old pliers have been oxidized to iron oxide (Fe_2O_3), or rust.



Potassium (K) and water (H_2O)

chemical change

Potassium reacting with water, to produce a flame, indicating a reaction is occurring.

Dramatic change of properties

- Two deadly chemicals, sodium (Na) and chlorine (Cl), react violently to form edible table salt (NaCl)
- Properties can change dramatically upon reactions

$$2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$$

 +  → 

sodium metal | chlorine gas | table salt

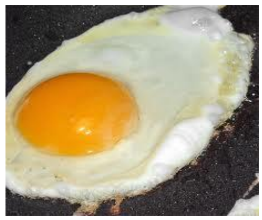
Other signs of chemical reaction

Nickel (Ni), a solid metal, is mixed with a colorless solution of hydrochloric acid (HCl) in a test tube

- Change in color
- Solid dissolves
- Gas bubbles appear

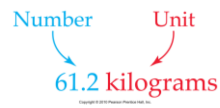
 Chapter One 18

A chemical or physical change?



1.7 Physical Quantities

- Physical quantities are physical properties that can be measured on a number scale
- They <u>always</u> have 2 parts:
  – A number …
  – … followed by its units.*



*It's minus one point every time you forget the units on an exam. Please don't do this!

The Metric System*

- There are <u>base units</u> and <u>prefixes</u>
  – base units indicate the type of property: length, mass, temperature, etc.
    - SI and metric base units are similar
  – prefixes form units that differ by powers of ten

TABLE 2.1 Some SI and Metric Units and Their Equivalents

QUANTITY	SI UNIT (SYMBOL)	METRIC UNIT (SYMBOL)	EQUIVALENTS
Mass	Kilogram (kg)	Gram (g)	1 kg = 1000 g = 2.205 lb
Length	Meter (m)	Meter (m)	1 m = 3.280 ft
Volume	Cubic meter (m^3)	Liter (L)	1 m^3 = 1000 L = 264.2 gal
Temperature	Kelvin (K)	Celsius degree (°C)	See Section 2.9
Time	Second (s)	Second (s)	—

*There is no such thing as "English units" in chemistry. Most science agrees.

Other units are "derived" from the base units

Derived Units

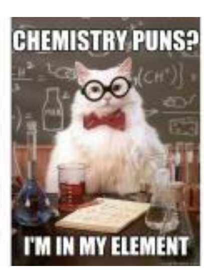
Quantity	Definition of Quantity	SI Unit
Area	Length squared	m^2
Volume	Length cubed	m^3
Density	Mass per unit volume	kg/m^3
Speed	Distance traveled per unit time	m/s
Acceleration	Speed changed per unit time	m/s^2
Force	Mass times acceleration of object	$kg \cdot m/s^2$ (= newton, N)
Pressure	Force per unit area	$kg/(m \cdot s^2)$ (= pascal, Pa)
Energy	Force times distance traveled	$kg \cdot m^2/s^2$ (= joule, J)

Know the prefixes in blue (nano- to mega-)

Table 1.2 ▶ The Prefixes Used in the SI System (Those most commonly encountered are shown in blue.)

Prefix	Symbol	Meaning	Exponential Notation*
exa	E	1,000,000,000,000,000,000	10^{18}
peta	P	1,000,000,000,000,000	10^{15}
tera	T	1,000,000,000,000	10^{12}
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
—	—	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}
femto	f	0.000000000000001	10^{-15}
atto	a	0.000000000000000001	10^{-18}

Let's take a 5-minute break.



Pop quiz: Which glass of water to drink?

The glasses appear the same at the macro scale, and yet they are very different at the microscale.

Giardia, a microscopic contaminant

What is smaller than microscale?

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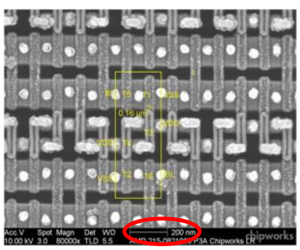
giga	G	1,000,000,000	10^{9}
mega	M	1,000,000	10^{6}
kilo	k	1,000	10^{3}
hecto	h	100	10^{2}
deka	da	10	10^{1}
—	—	1	10^{0}
deci	d	0.1	10^{-1}
centi	c	0.01	10^{-2}
milli	m	0.001	10^{-3}
micro	μ	0.000001	10^{-6}
nano	n	0.000000001	10^{-9}
pico	p	0.000000000001	10^{-12}
femto	f	0.000000000000001	10^{-15}
atto	a	0.000000000000000001	10^{-18}

Can you visualize a billionth?

Millions or even billions of "devices" in a small computer chip is common.

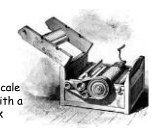
What do these devices look like?



An electron microscope shows individual devices, measured in nanometers.

Can you think of other things measured in billions/billionths?

A brief history of the smaller and smaller (Not on any exam.)



A human-scale machine with a hand crank

- Millimeter sized, interchangeable gears
  - Eli Whitney's cotton gin in 1793

- Micrometer tolerances & computer aided design (CAD)
  - Toyota's continuous improvement (kaizen) over the 20th Century
- But this is not small enough for digital computing!

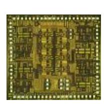
A digital adding machine made of vacuum tubes.

hearing aid vacuum tube 35x10 mm machined to micrometer tolerances.

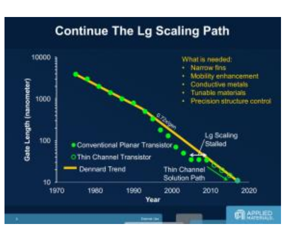
Solid state technology (not on exam)

- Transistor invented 1947
  - Layers of solid materials (semiconductors) with novel electrical properties
  - No moving parts – chemical synthesis/etching
- Manufactured at exponentially decreasing scale over time
  - 1970s ~3 **micro**meter gate length
  - 2020 10 **nano**meter gate length

two 1970s radio transistors



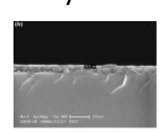
modern integrated circuit (IC) with billions of transistors



nano everywhere!

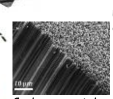
flexible solar panel thin film photovoltaic technology

nano-crystal studded glass changes color to filter light



SEM image of 300 nm VO_2 thin film on silicon water. It could generate electricity instead of dissipating heat.

SPADA

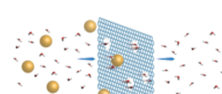


Carbon nanotubes are 100x stronger than steel!

nanospheres for drug delivery

"nano-swords" for antimicrobial protection… on my sneakers!

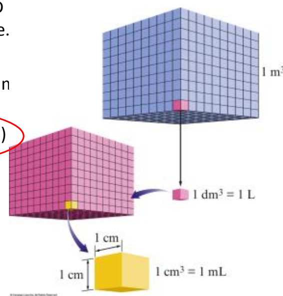
Smart fingertip electronics



graphene, a single layer of carbon, acts as a water filter

1.8 Volume is "derived" from length

- Measure of the amount of 3-D space occupied by a substance.
- SI unit = cubic meter (m^3)
- Commonly measure solid volun in cm^3.
- 1 mL = 1 cm^3 or 1 cc (cubic cm)



1.9 Measurement uncertainty (sig figs)

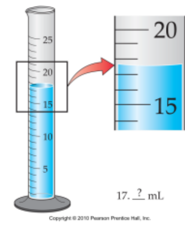
- Chemists follow a convention when making any measurement
  - State all known digits from the measurement device
  - Then guess the very last digit

Step 1. Each horizontal line indicates 1 mL.

Step 2: The liquid level is clearly above 17 mL and clearly below 18 mL.

Step 3. Guess the last digit. It's about half way between 17 and 18 mL, so a good guess would be 17.5 mL. Other readings such as 17.6 mL or 17.4 mL would also be acceptable.

Step 4: The measurement has 3 significant figures, and the last is implied to be a guess.

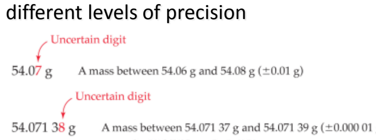


- How many sig figs on top?

- How many sig figs on bottom?

Why do we use sig figs???

- Below are two measurements of the mass of the same object from two different balances
- The *same* quantity is being *described* at two different levels of precision



The chemist measuring 54.07138 g (7 sig figs) has a more precise (and thus more costly) instrument than the one reporting only 4 sig figs.

You can "read between the lines" of a lab report to understand the precision of the equipment used for the measurements. This helps the reader understand the uncertainty (amount of potential error) in the results.

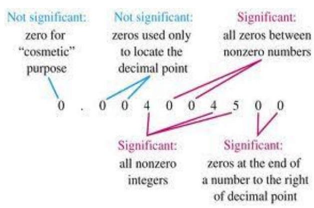
Counting sig figs I

- Nonzero integers are always **significant** figures
  - 3456 has 4 sig figs
  - 3456.789 has 7 sig figs
- Zeros in the middle ("captive zeros") are significant, just like any digit
  - 3406, 3006, and 3056 all have 4 sig figs
  - 3056.789, 3406.789, 3450.789, 3456.089, 3056.709, 3400.709, 3000.009 (and other variations) all have 7 sig figs
- Zeros up front ("leading zeros") don't count
  - 03456 and 0003456 are the same numerically as 3456.
    - all have 4 sig figs.
  - Sometimes your calculator, instrument, or odometer will print out leading zeros. Just ignore these.

Counting sig figs II

- Trailing zeros (at end of number) are significant only if there is a decimal point
  - 1.500 has 4 sig fig
    - precise to ±0.001 (last digit is a guess)
    - Assume the true value is between 1.499 and 1.501
  - 1500 has only 2 sig figs
    - Precise to the hundreds digit (second from left) or ±100
    - Assume the true value is between 1400 and 1600
  - 1500. has 4 sig figs
    - Note the "dot" or decimal after the last zero!
    - Special notation for Chem 30A. (Scientific notation is better.)
    - Here, implies precision to the ones digit or ± 1
    - Assume the true value is between 1499 and 1500

Summary of zeros



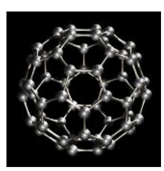
The dot (for Intro Chem only!!!)

- What's the distance to the sun?
  - 150. million kilometers (note the dot – 3 sig fig)
  - or 150. x 10^6 kilometers
  - or 1.50 x 10^2 x 10^6 kilometers
  - or 1.50 x 10^8 kilometers

- 1.50 x 10^8 km clearly has 3 sig figs
  - 150,000,000 km would be ambiguous (looks like 2 sig fig??)
  - **Scientific notation is vastly superior to the "dot" notation**
  - Especially for really big or really small numbers

Exact numbers

- Some numbers are exact.
  - There is no guess here. All digits are significant.
  - Counting
    - There are 32 students in the classroom. (2 sig fig)
    - There are 30 students in the classroom. (also 2 sig fig)
    - Buckminsterfullerene is a molecule with 60 carbons (2 sig fig)
  - Definition
    - A triangle has (exactly) 3 sides
    - 1 inch = 2.54 cm (exactly by definition)
    - Diameter of a circle is half (½) the radius.



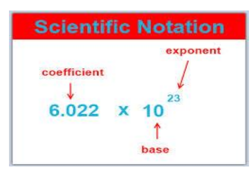
Buckminsterfullerene (C_{60})

1.10 Scientific Notation *[study at home]*

- Technique used to express very large or very small numbers.
- Expresses a number as a product of a number between 1 and 10 and the appropriate power of 10.

$$93{,}000{,}000 = 9.3 \times 10{,}000{,}000 = 9.3 \times 10^7$$

Number between 1 and 10 — Appropriate power of 10 ($10{,}000{,}000 = 10^7$)



Using Scientific Notation

- If the decimal point is moved to the left, the power of 10 is positive.

  $345 = 3.45 \times 10^2$

- If the decimal point is moved to the right, the power of 10 is negative.

  $0.0671 = 6.71 \times 10^{-2}$

That's a wrap!

- Get started with Homework #1 while the material is fresh.
  - Be sure to do your own work
- Studying while lecture material is fresh will greatly reduce your required study time!
- If you get stuck with the homework, ask for help from your professor (email), a classmate, a friend, or tutor.
- Bring printouts (lab manual, lecture notes, HW #2) to the next class meeting.
- Consider reading through Ch 2.3 (isotopes) before next class meeting.