Module 1:
Matter and Measurement

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Objectives

- Define and apply the scientific method.
- Define and recognize the states of matter.
- Recognize and distinguish between pure substances and mixtures.
- Distinguish between physical and chemical changes.
- Perform calculations using numbers with SI units.
- Convert between base units and units containing prefixes.
- Recognize the temperature scales and convert between them.
- Convert numbers from regular notation to scientific notation.
- Perform calculations to the correct number of significant figures.
- Define accuracy and precision.
- Perform chemical calculations using dimensional analysis.

Table of Contents

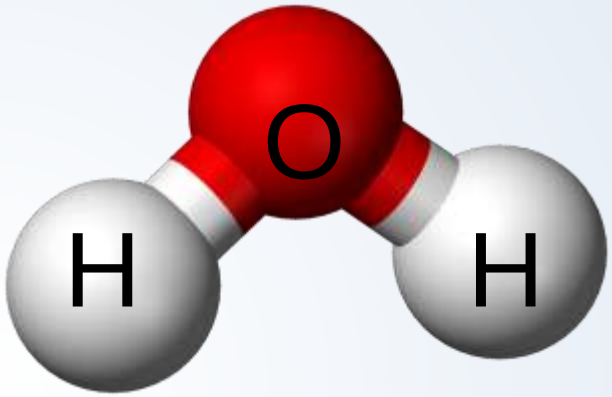
Introduction: The Study of Chemistry

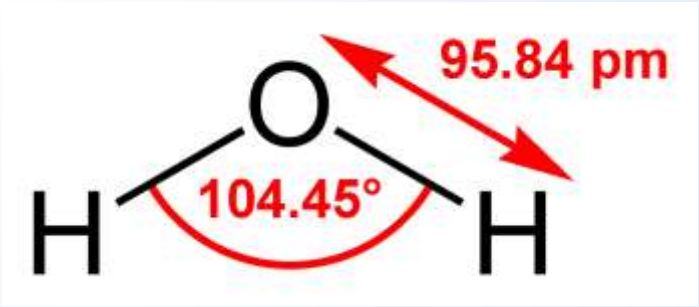
- Chemistry is the science of matter, especially its chemical reactions, but also its composition, structure and properties.

Introduction: The Study of Chemistry

- Study of matter
  - Anything that has mass and takes up space
  - Made up of tiny particles called atoms
  - Atoms combine together to form molecules
  - When enough molecules are present, we can see them.
- Macroscopic vs. microscopic

Introduction: The Study of Chemistry





Macroscopic vs. Microscopic

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Water-2D-labelled by Benjah-bmm27 PD http://commons.wikimedia.org/wiki/File:Water-2D-labelled.png

Introduction: The Study of Chemistry

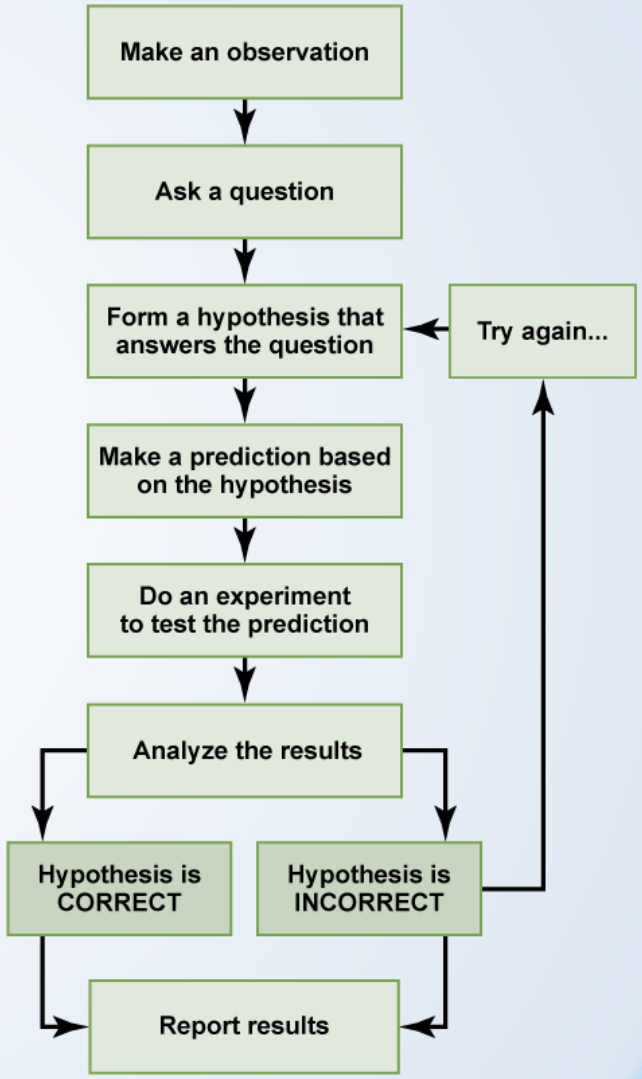
- Helps us explain our world
- Central science

Scientific Method

- All scientists:
  - Gather and categorize information
  - Continually question the world and what we think we know
  - Follow a specific process

Scientific Method

- Scientific process of inquiry.
- Hypotheses are possible explanations.
- Experiments are done to DISPROVE hypotheses.
- Adjust hypotheses based on experimental findings.
- Hypotheses that are unable to be disproven after several tests are eventually considered theories.
- If a scientific theory holds up to constant experimentation, they are eventually considered laws.



Concept Quiz

- Why is it important to try and disprove (rather than prove) your hypothesis?

Concept Quiz

- What is the difference between a hypothesis and a theory?

Concept Quiz

- Give at least one situation where you used the scientific method in the last 24 hours.

Classification of Matter

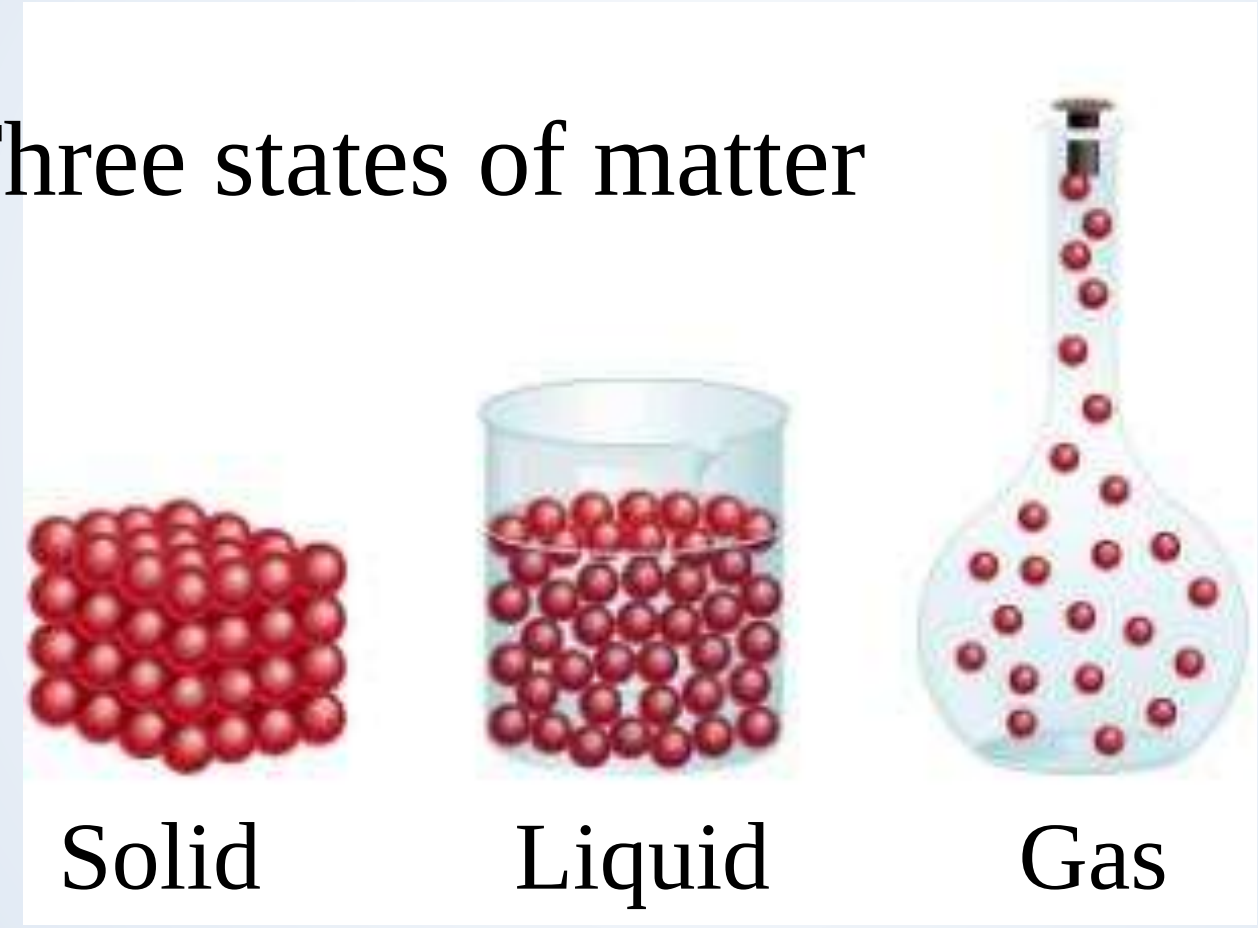
- Scientific Method starts with observations.
- Observe and classify matter.

Classification of Matter

- Matter is anything having mass and occupying space.
- Can exist as a
  - Solid
  - Liquid
  - Gas

States of Matter

- Three states of matter



States of Matter

1. Solid
   - Definite volume and shape.
   - Rigid, tightly packed particles.
   - Slight vibration is only motion possible.
   - Cannot be compressed.

States of Matter

Liquid

- Definite volume but variable shape (takes shape of container).
- Close, slow moving particles.
- Cannot be compressed.

Parafina posted by Chemik10 CC-BY-SA 2.5 http://commons.wikimedia.org/wiki/File:Liquid_paraffin_in_beaker.jpg
Black Friday Crowd Rushing into Urban Outfitters posted by Jerry Bailey 2011 Standard YouTube License.
https://www.youtube.com/watch?v=DigiWS1YhxI
Particles in a liquid by leilaghboyle http://youtu.be/ymcVs2B5ydk Standard YouTube License

States of Matter

3. Gas/Vapor
   - Variable volume AND variable shape
   - Particles are far apart
   - Particles are in rapid random and constant motion.

Smoke Texture by Caleb CC-BY https://flic.kr/p/5RZseH

Gas – colliding particles w/o gravity force by numerical physics. http://youtu.be/iC3bfyP6Wuk Standard YouTube License

Concept Quiz

- How can you distinguish between the states of matter?

Classification of Matter

Matter can be either

1. Pure Substances

   Can only be split apart by chemical methods

2. Mixtures

   Can be separated by physical means

Pure Substances

Elements – found on the periodic table.

- Can be atoms or molecules

Examples:

O_2

Na

Fe

Nitrogen 3-D PD http://commons.wikimedia.org/wiki/File:Nitrogen-3D-vdW.png#mediaviewer/File:Nitrogen-3D-vdW.png

Pure Substances

Compounds – chemically bonded elements.

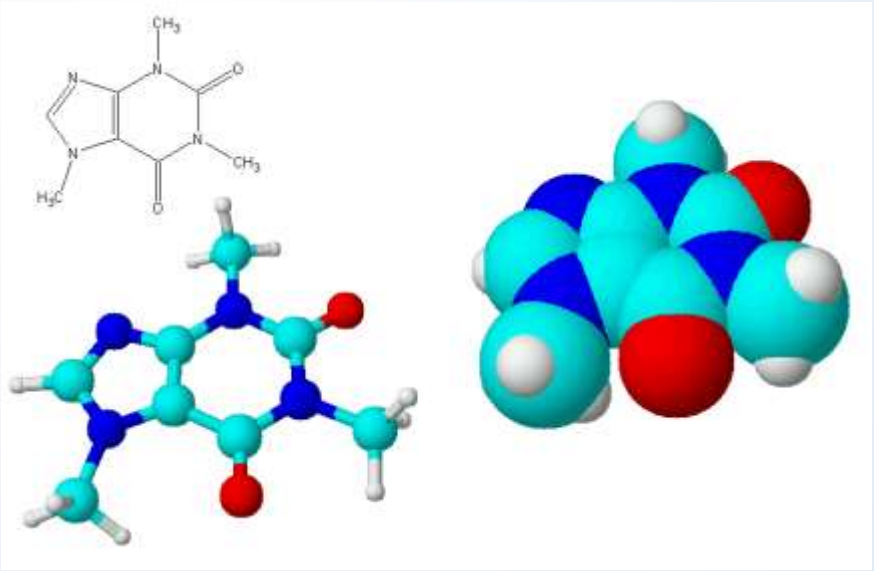
– cannot be separated by physical methods.

Examples:

H_2O

NaCl

Caffeine



Caffine. Gemaakt met ACD LABS en paint en Jasc Paint Shop Pro
http://commons.wikimedia.org/wiki/File:Cafe%C3%AFne.png#mediaviewer/File:Cafe%C3%AFne.png

Mixtures

Mixtures

- Physically mixed but not chemically combined.
- Combination of more than one substance.
- Can be either homogeneous or heterogeneous.

Homogeneous Mixtures

The same all the way throughout.

Examples

- Kool-Aid
- Coffee
- Brass

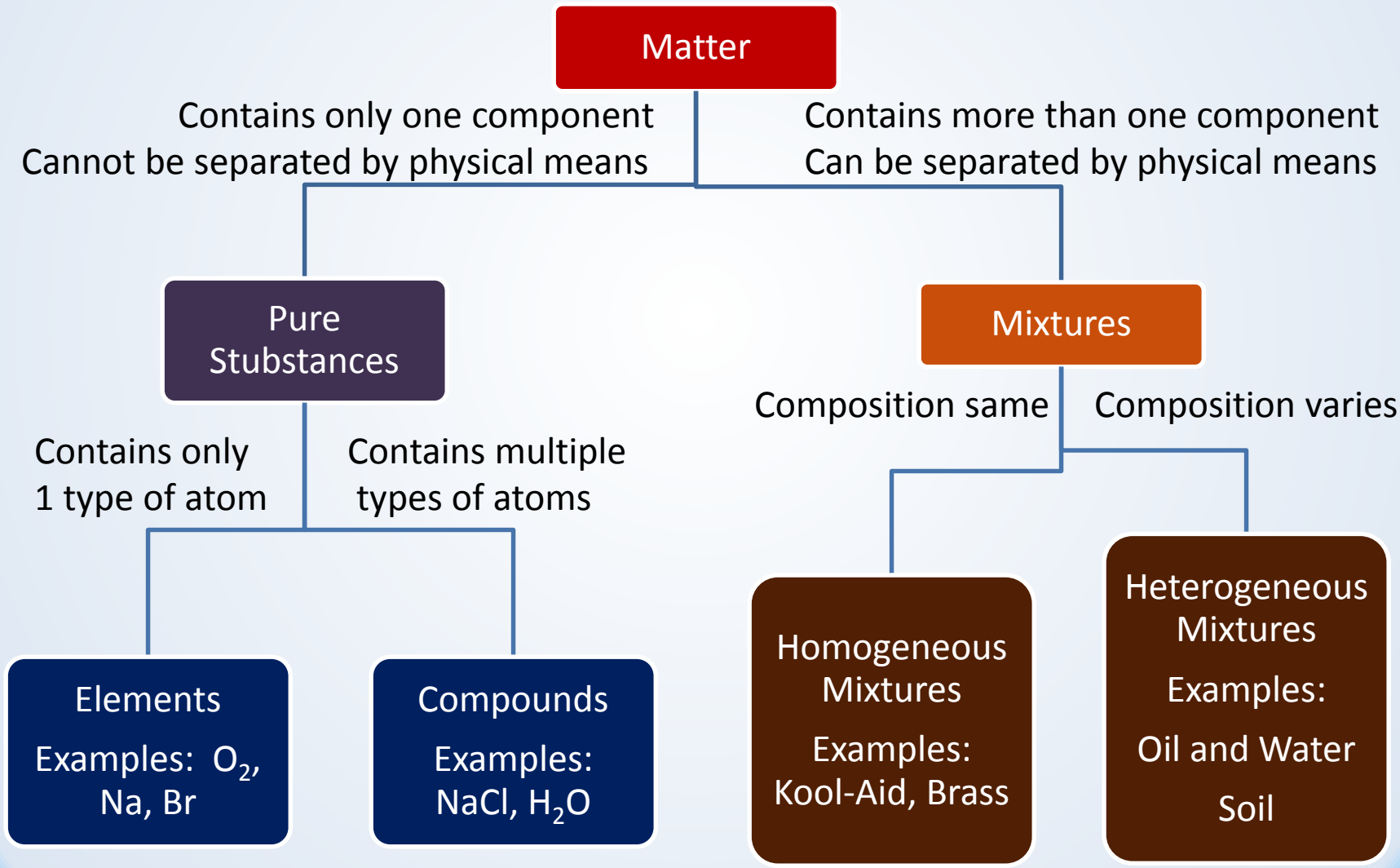
Heterogeneous Mixtures

Different components are visible.

Examples

- Muddy water
- Raisin Bran
- Soil

Classification of Matter



Concept Quiz

- Classify the following:
  - Jar of jelly beans — Heterogeneous Mixture
  - Whipped cream — Homogeneous Mixture
  - Air — Closed container = homogeneous mixture, open container = heterogeneous mixture
  - Carbon dioxide (CO_2) — Pure Substance (Compound)
  - Steel — Homogeneous Mixture
  - Nitrogen gas (N_2) — Pure Substance (Element)
  - Gasoline — Homogeneous Mixture

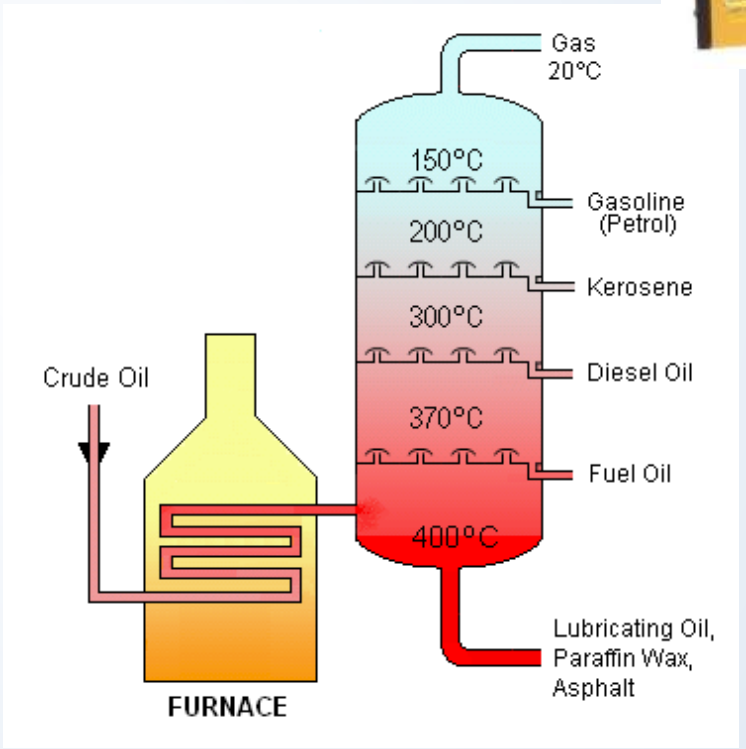
Physical Properties

- Any quality that can be observed without changing the chemical composition of the substance.
  - Mass
  - Density
  - Color
  - Texture
  - Magnetic
  - Malleable
  - Ductile
  - Freezing Point
  - Melting Point

Melting icecubesPublic Domainview terms Mysid
http://commons.wikimedia.org/wiki/File:Melting_icecubes.gif#mediaviewer/File:Melting_icecubes.gif

Physical Properties

- Can be used to purify substances
  - Methods include
    - Chromatography
    - Distillation
    - Sublimation
    - Solubility



Physical Changes

- A change that does not alter the chemical composition of the substance.
  - Cutting
  - Melting
  - Freezing
  - Boiling
  - Dissolving

Melting Gallium Spoon Standard YouTube License http://youtu.be/cvRcUeWjBu0

Chemical Properties

- Any quality that can be observed when changing the composition of the substance.
  - Flammability
  - Reactivity
  - Oxidation

Chemical Changes

- A change that does alters the chemical composition of the substance.
- Changes it to a new substance.
  - Burning
  - Oxidizing
  - Reacting

Concept Quiz

- Classify the following as physical or chemical:
  - A log burns in the campfire.
  - Toasting marshmallows.
  - You dissolve sugar in your tea.
  - You boil water.
  - Cooking pasta.
  - A raft floats in the pool.

Units of Measurement

- One type of scientific observation is a measurement.
  - Contains quantitative AND qualitative parts:
    - Number
    - Unit
- Examples:
  - 1.2 meters
  - 45 years old
  - 3.0×10^8 meters per second

SI Units

- Mass: the kilogram (kg)
- Time: the second (s)
- Temperature: the Kelvin (K)
- Electric Current: the ampere (A)
- Amount: the mole (mol)
- Luminous intensity: the candela (cd)
- Distance: the meter (m)

SI Units

- Mass vs. Weight

Concept Quiz

- What is the SI unit for
  - Mass?
  - Temperature?
  - Time?
  - Distance?
  - Amount?

SI Unit Prefixes

Prefix	Unit Abbrev.	Meaning	Example
giga	G	1,000,000,000	1 gigameter (Gm) = 10^{9} m
mega	M	1,000,000	1 megameter (Mm) = 10^{6} m
kilo	k	1000	1 kilometer (km) = 1000 m
hecto	h	100	1 hectometer (hm) = 100 m
deka	da	10	1 dekameter (dam) = 10 m
		1	1 meter (m)
deci	d	1/10	1 decimeter (dm) = 0.1 m
centi	c	1/100	1 centimeter (cm) = 0.01 m
milli	m	1/1000	1 millimeter (mm) = 0.001 m
micro	µ	1/1,000,000	1 micrometer (µm) = 10^{-6} m
nano	n	1/1,000,000,000	1 nanometer (nm) = 10^{-9} m
pico	p	1/1,000,000,000,000	1 picometer (pm) = 10^{-12} m

Derived Units

- Use two or more units to have a new unit type
  - Speed (m/s)
  - Density (g/mL)

Density

- Density of water is 1.0 g/mL
  - More dense: sink
  - Less Dense: Float

Amazing 9 Layer Density Column by Sick Science Standard YouTube License http://youtu.be/-CDkJuo_LYs

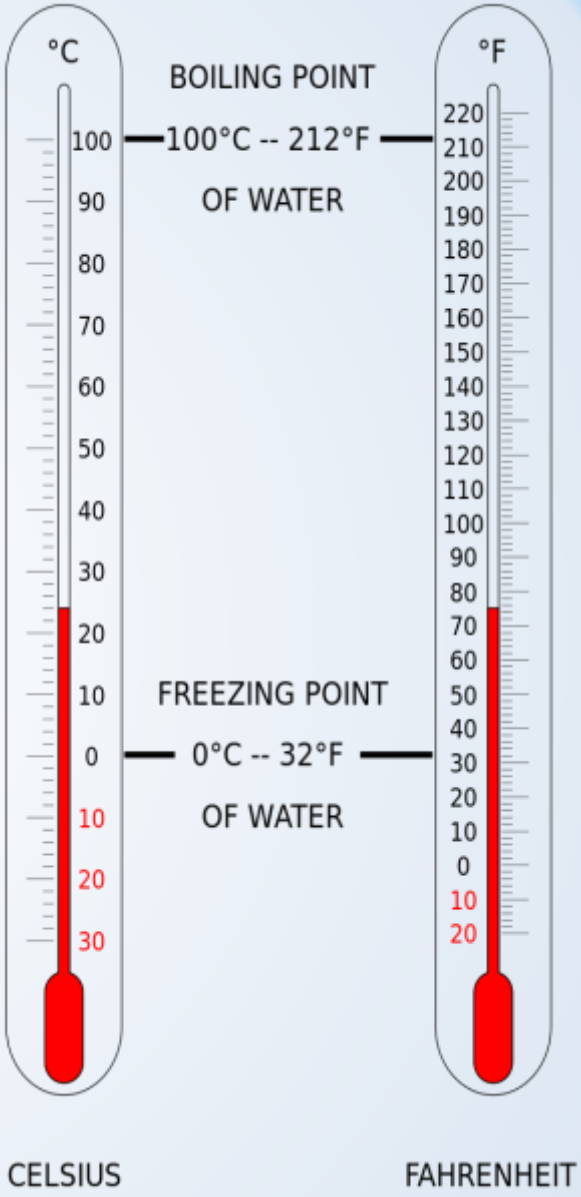
Temperature

- Fahrenheit seldom used
- Celsius more convenient because of 100 unit scale.

$$T_F = 9/5\ T_C + 32$$

or

$$T_C = (T_F - 32) \times 5/9$$



Temperature

- Absolute 0
  - Neither scale accounts for a temperature with NO heat or movement.
  - Needed a scientific scale.
  - Kelvin—the SI unit (preferred by science).
  - 0 K = -273.15 C

Temperature

- $T_K = T_C + 273.15$
- $T_C = T_K - 273.15$

Concept Quiz

- The temperature outside is 73°F. What is the temperature in °C and K?

22.8 C

295.9 K

Concept Quiz

- The temperature of liquid nitrogen is 77 K, what is the temperature in ◦C and ◦F?

-196 C

-321 F

Significant Figures

- All known numbers and 1 uncertain.
- In lab read from bottom of meniscus
- This would be read:

20.00 mL which has 4 SF

Significant Figures

- Rules
  - All nonzero numbers are significant

Examples	Number SF
12.4	3
8.9	2
4	1

Significant Figures

- Rules
  - Zeros in the middle of a number are significant.

Examples	Number SF
30.7	3
19.09	4
0.04002	4

Significant Figures

- Rules
  - Trailing zeros are significant ONLY if there is a period or designator.

Examples	Number SF
100	1
100.	3
0.2000	4

Significant Figures

- Rules
  - Leading zeros are never significant.

Examples	Number SF
0.02	1
0.89	2
0.001004	4

Concept Quiz

- How many significant figures are in

1	0
10	0.1
100	0.01
1000	0.001
1000.	0.0010

Significant Figures

- Exact numbers contain infinite significant figures.

Examples:

- 5 pencils
- 1 m = 100 cm
- 12 in = 1 ft

Significant Figures

- Calculations
  - When you multiply and divide your answer should have the same number of significant figures as the number with fewest.
  - When you add or subtract your answer should have the same number of decimal spaces as the number with the fewest.

Concept Quiz

- Answer the following to the correct number of significant figures.

1. 12.4 x 0.2
2. 31.4 + 9.17
3. 100 x 14
4. 100 / 17

1. 2
2. 40.6
3. 1000
4. 6

Measurement Uncertainty

- Scientific Notation
  - Useful for dealing with large or small numbers.
  - Contains a coefficient and a power of ten.
  - All numbers in the coefficient are significant.

Examples:

1.42×10^{2} m = 142 m

3.0×10^{8} m/s = 30,000,000 m/s

5.1×10^{-4} g = 0.00051 g

Concept Quiz

Convert the following to scientific notation: (assume 3 significant figures for each example here).

- 6700000
- 0.0001235
- 0.600800
- 3.3333

Accuracy and Precision

- Accuracy – measuring close to the true value.
- Precision – subsequent measurements are close to one another.

High Accuracy
Low Precision

Low Accuracy
High Precision

Dark Evil PD http://commons.wikimedia.org/wiki/File:High_accuracy_Low_precision.svg#mediaviewer/File:High_accuracy_Low_precision.svg
Dark Evil PD http://commons.wikimedia.org/wiki/File:High_precision_Low_accuracy.svg#mediaviewer/File:High_precision_Low_accuracy.svg

Error

- Error is the difference between the true value and the measured value.

Examples:

- Scales reading too high
- Gas gage is not calibrated
- Spilling after measuring the liquid in your graduated cyllinder in lab

Percent Error

More important to consider the percent error than real numbers.

$$\% \text{ error} = \frac{\left| \text{Accepted} - \text{Measured} \right|}{\text{Accepted}} \times 100$$

http://www.pstcc.edu/nbs/WebPhysics/Experiment%2010web.htm

Concept Quiz

Calculate the percent error:

A 14.5 kg child is weighed while holding a toy causing her weight to be read as 16.9 kg.

16.6 %

Dimensional Analysis

- A way to convert between 1 unit and another.
- Start with the given.
- Consider all equalities/ conversion factors.
- Plug in so the units cancel.

Dimensional Analysis

- Convert 1.75 inches to feet.
  - We are given in
  - We need to convert to feet
  - We know there are 12 inches in every foot which we can write as an equality: 12 inches = 1 feet
  - If both values in an equality are equal we can write them as a fraction (1/1 = 1)

  12 in / 1 ft or 1 ft / 12 in
  - Set up the problem as

Dimensional Analysis

1.75 in → Ft

We can do this in one step because we have an equality that contains both units.

12 in = 1 ft

Set it up so the units cancel

$$1.75\ \text{in} \left| \frac{1\ \text{ft}}{12\ \text{in}} \right| = 0.145833\ \text{ft} = 0.146\ \text{ft}$$

Remember SF is determined by the 1.75 because this only has 3 SF and not the infinite like the equality

Concept Quiz

Convert:

12.5 mm to nm 12.5 x 106 nm

1020 cL to L 10.2 L

Concept Quiz

Use dimensional analysis to determine the cost of a round-trip drive from Norfolk to San Diego.

Concept Quiz

Use dimensional analysis to determine how many seconds are in 5.4 centuries.

Problem Solving

- Remember to always make a plan.
- Consider the starting and ending units.
- Make a list of equalities or conversion factors going to be used.
- Make sure your units are written so they cancel.
- DO NOT skip these steps.