Chapter 1 Lecture Notes: Science and Measurements

Educational Goals

1. Explain, compare, and contrast the terms **scientific method**, **hypothesis**, and **experiment**.
2. Compare and contrast scientific **theory** and **scientific law**.
3. Define the terms **matter** and **energy**. Describe the three phases (states) of matter and the two forms of energy.
4. Describe and give examples of **physical properties** and **physical change.**
5. Perform **unit conversion** calculations.
6. Express and interpret numbers in **scientific (exponential) notation**.
7. Explain the difference between the terms **accurate** and **precise**.
8. Know and use the rules for **significant figures**.
   - Given a value, determine the number of significant figures.
   - Use the correct number of significant figures to report the results of calculations involving measured quantities.

Science is a _______________ for gaining knowledge and understanding of reality.

It produces ***generalizations*** with _____________________value.

The Scientific Method

There are two ways to do science: ***scientific theory*** and ***scientific law***.

- It is important to note that *both* methods are used to acquire predictive power and both begin with _____________________

Scientific Theory

Other words for **theory** are ____________ or _________________.

- Scientific theory uses models/explanations to make sense of observables. Often, a first guess at a model is proposed.
- The first guess is called a _________________.

The hypothesis can usually be tested by experiment or additional observations.

If the hypothesis continues to be validated by experiment or new observations, it becomes ____________.

In the healthcare field, another word for theory or model is ______________.

Scientific Law

A scientific law is simply ***a*** ________________ ***about something that generally occurs***.

Note that in using scientific law, _______ explanation (model) is given.

Scientific law can be contrasted with scientific theory that involves proposing a model or explanation for what is observed.

Chemistry

Chemistry is the study of matter and how it interacts with other _____________ and/or _____________.

Matter and Energy

Matter is anything that has _______________ and occupies ______________.

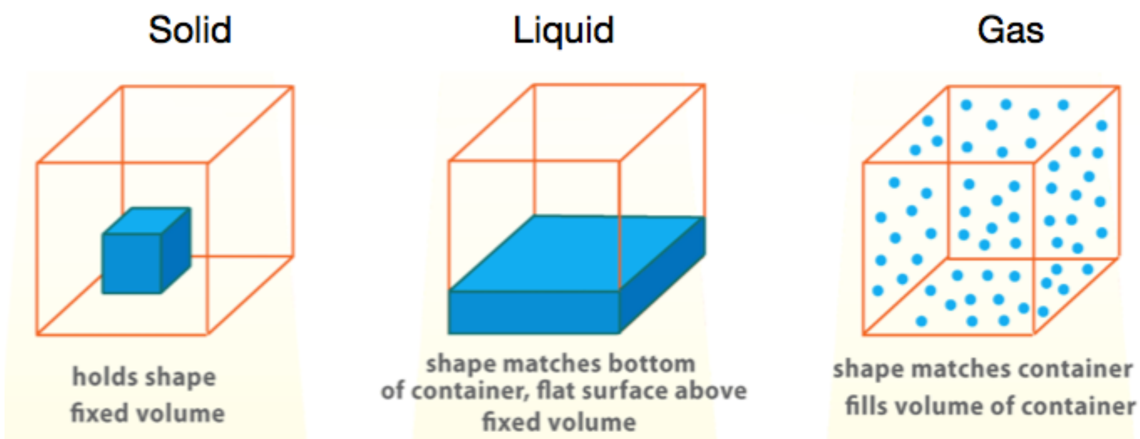
We can describe matter in terms of________________ __________________, those characteristics that can be determined without changing it into a different substance.

- Example: Sugar is white, tastes sweet, and can be crushed into powder. Crushing sugar does not change sugar into something else.

Matter can also be described in terms of its ______________ ***properties***. Chemical properties of substances describe *how they are converted to new substances* in processes called chemical reactions.

- Example: Carmalization of sugar

Matter is typically found in one of three different physical ___________ (sometimes called _________).



Example: Ice **Example: water** **Example: steam**

Changing the phase of matter, converting matter between solid, liquid, and gas is considered a *physical change* because the identity **does not** change.

- Examples of phase changes are: melting, boiling water to make steam, and melting an iron rod.

Energy

Energy is commonly defined as the ability to do ________.

Energy can be found in two forms, ______________ *energy* and _____________ *energy*.

Potential energy is ___________ energy; it has the potential to do work.

- An example of potential energy is water stored in a dam. If a valve is opened, the water will flow downhill and turn a paddle connected to a generator to create electricity.

Kinetic energy is the energy of _____________.

- Any time matter is moving, it has kinetic energy.

An important law that is central to understanding nature is: **matter will exist in the lowest possible energy state**. Another way to say this is "if matter can lose energy, it will always do so."

Understanding Check: Kinetic Energy vs. Potential Energy

Which are mainly examples of ***potential energy*** and which are mainly examples of ***kinetic energy***?

a) A mountain climber sits at the top of a peak.
b) A mountain climber rappels down a cliff.
c) A hamburger sits on a plate.
d) A nurse inflates a blood pressure cuff.

Units of Measurements

Measurements consist of two parts – a ________________ and a____________________.

SI Units and Their Symbols

Quantity	SI Unit Name	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	Kelvin	K

Commonly Used Units and Their Symbols

Quantity	Unit Name	Symbol
Length	foot inch	ft in
Mass	gram pound	g lb
Volume	Liter	L
Temperature	Fahrenheit Celsius (or Centigrade)	^{0}F ^{0}C

Scientific Notation and Metric Prefixes

Scientific Notation

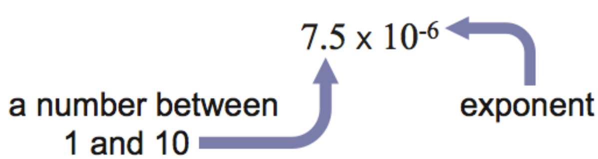
When making measurements, particularly in science and in the health sciences, there are many times when you must deal with very large or very small numbers.

Example: a typical red blood cell has a diameter of about 0.0000075 m.

In ________________ __________________(exponential notation) this diameter is written 7.5×10^{-6} m.

Values expressed in scientific notation are written as a number between _____ and _____ multiplied by a power of 10.

The superscripted number to the right of the ten is called an *exponent*.



- An exponent with a positive value tells you how many times to **multiply** a number by 10.

$$3.5 \times 10^4 = 3.5 \times 10 \times 10 \times 10 \times 10 = 35000$$

- An exponent with a negative value tells you how many times to **divide** a number by 10.

$$3.5 \times 10^{-4} = \frac{3.5}{10 \times 10 \times 10 \times 10} = 0.00035$$

Converting from Regular Notation to Scientific

1) Move the decimal point to the right of the first (right-most) non-zero number
- The exponent will be equal to the number of decimal places moved.

2) When you move the decimal point to the left, the exponent is positive.

$$35000 = 3.5 \times 10^{4}$$

$$285.2 = 2.852 \times 10^{2}$$

$$8300000 = 8.3 \times 10^{6}$$

3) When you move the decimal point to the right, the exponent is negative.

$$0.00035 = 3.5 \times 10^{-4}$$

$$0.0445 = 4.45 \times 10^{-2}$$

$$0.00000003554 = 3.554 \times 10^{-8}$$

Understanding Check: Convert each number into scientific notation.

a) 0.0144
b) 144
c) 36.32
d) 0.0000098

Converting from Scientific Notation to Regular Notation

You just learned how to convert from regular numerical notation to scientific notation. Now let's do the reverse; convert from scientific notation to regular notation.

Step 1: Note the value of the ***exponent***.

Step 2: The value of the exponent will tell you which direction ***and*** how many places to move the decimal point.

- If the value of the exponent is **positive**, remove the power of ten and move the decimal point that value of places to the ***right***.
- If the value of the exponent is **negative**, remove the power of ten and move the decimal point that value of places to the ***left***.

Example: Convert 3.7×10^{5} into regular notation.

Step 1: Note the value of the ***exponent***: The exponent is **positive 5**.

Step 2: The value of the exponent will tell you which direction and how many places to move the decimal point.

- If the value of the exponent is **positive**, remove the power of ten and move the decimal point that value of places to the ***right***.
  - We will move the decimal point 5 places to the ***right***.

3.7 → 3.70000 → 370000

When the decimal point is **not shown** in a number, as in our answer, it is assumed to be ***after the right-most digit***.

Let's do another example: Convert 1.604 x 10^{-3} into regular notation.

Step 1: Note the value of the ***exponent***: The exponent is ***negative* 3**.

Step 2: The value of the exponent will tell you which direction and how many places to move the decimal point.

- If the value of the exponent is **negative**, remove the power of ten and move the decimal point that value of places to the ***left***.
    - We will move the decimal point 3 places to the ***left***.

Understanding Check: Convert the following numbers into regular notation. a) 5.2789 x 10^{2} b) 1.78538 x 10^{-3} c) 2.34 x 10^{6} d) 9.583 x 10^{-5}

Measurements and Significant Figures

There are three important factors to consider when making measurements:

1) **accuracy**

2) **precision**

3) **significant figures**

_____________________ is related to how close a measured value is to a true value.

Example: Suppose that a patient's temperature is taken twice and values of 98 °F and 102 °F are obtained. If the patient's true temperature is 103 °F, the second measurement is more *accurate*.

___________________ is a measure of reproducibility.

Example: Suppose that a patient's temperature is taken three times and values of 98 °F, 99 °F, and 97 °F are obtained. Another set of temperature measurements gives 90 °F, 100 °F, and 96 °F.

- The values in the first set of measurements are closer to one another, so they are more precise than the second set.

The quality of the equipment used to make a measurement is one factor in obtaining accurate and precise results. The ability of the human operator to correctly use the measuring device is another factor.

Significant Figures

One way to include information on the ______________ of a measured value (or a value that is calculated using measured values) is to report the value using the correct number of significant figures.

The precision of a measured value can be determined by the ___________ -most decimal place reported.

- The names and precision of the decimal places for the number **869.257** are shown below:

Digit in Number	8	6	9	2	5	7
Decimal Place Name	Hundreds (100's)	Tens (10's)	Ones (1's)	Tenths ($1/10^{th}$'s)	Hundredths ($1/100^{th}$'s)	Thousandths ($1/1000^{th}$'s)

A simple way to understand significant figures is to say that a digit is significant if we are _________ of its value.

Method for Counting Significant Figures

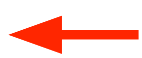
Measured and calculated values should be reported using significant figures. We can look at a numerical value and determine the number of significant figures as follows:

- If the decimal point is ____________, starting from the ***left***, count all numbers (including zeros) beginning with the first non zero number.
- If the decimal point is ____________, starting from the ***right***, count all numbers (including zeros) beginning with the first non zero number.
- When numbers are given in scientific notation, **do not** consider the power of 10, only the value before " $\mathbf{x\ 10^n}$."

Example: If the botanist reported the age of the tree as **500 years**, how many significant figures are given?

Note that although the decimal point is implied to be after the right-most zero, it is **absent** (not shown explicitly), therefore we use the decimal point **absent** rule shown above; if the decimal point is **absent**, starting from the ***right***, count all numbers (including zeros) beginning with the first non zero number.

- We will start inspecting each digit from right (to left) as shown by the arrow.
- We will start counting when we get to the first non zero number.

500 

We do not count the first two zeros, but start counting at the **5**. Therefore, there is **one** significant figure present.

Example: If the botanist reported the age of the tree as **500.** years (note the decimal point present), how many significant figures are given?

Note that in this case, the decimal point is **present** (shown), therefore we use the decimal point **present** rule shown above; if the decimal point is **present**, starting from the ***left***, count all numbers (including zeros) beginning with the first non zero number. We will start inspecting each digit from left to right as shown by the arrow. We will start counting when we get to the first non zero number.

 500.

We begin with the **5**, then count <u>all</u> numbers ***including zeros***. In this case, the two zeros are also significant. Therefore there are **three** significant figures present.

Outside of the science fields, "**500**" and "**500.**" are generally thought of as equivalent, however, the use of significant figures tells us that when we write "**500.**" (with the decimal point present) we know that number one hundred times more precisely than when we write "**500**" (without the decimal point). We have precision to the "ones" decimal place in "**500.**" vs. precision to the "hundreds" place in "**500**".

Here are some other examples:

Example: How many significant figures are contained in 0.00045?

Note that in this case, the decimal point is **present** (shown). We will start inspecting each digit from left to right as shown by the arrow. We will start counting when we get to the first non zero number.

→ 0.00045

We begin with the **4**, then count <u>all</u> numbers ***including zeros***. Therefore there are **two** significant figures present.

Example: How many significant figures are contained in 0.0002600?

Note that in this case, the decimal point is **present** (shown). We will start inspecting each digit from left to right as shown by the arrow. We will start counting when we get to the first non zero number.

→ 0.0002600

We begin with the **2**, then count <u>all</u> numbers ***including zeros***. Therefore there are **four** significant figures present.

Example: How many significant figures are contained in 7080?

If the decimal point is **absent**, starting from the ***right***, count all numbers (including zeros) beginning with the first non zero number. We will start inspecting each digit from right (to left) as shown by the arrow. We will start counting when we get to the first non zero number.

7080 ←

We do not count the first zero, but start counting at the **8,** and then count ***all*** *numbers **(including zeros)***. Therefore, there are **three** significant figures present.

Understanding Check: Specify the number of significant figures in each of the values below.

a) 23.5	f) 6200.
b) 0.0073000	g) 6200.0
c) 6.70	h) 0.6200
d) 48.50	i) 0.62
e) 6200	j) 930

Significant Figures in Scientific Notation

When numbers are given in scientific notation, **do not** consider the power of 10, only the value before "**x 10^n**."

Examples: How many significant figures are contained in each of the values shown below?

a) 5 x 10^2 **one** significant figure

b) 5.0 x 10^2 **two** significant figures

c) 5.00 x 10^2 **three** significant figures

When converting back and forth from standard numerical notation to scientific notation, the number of significant figures used **should not change**.

Understanding Check: Write each measured value in ***scientific notation***, being sure to use *the correct number of significant figures*.

a) 5047
b) 87629.0
c) 0.00008
d) 0.07460

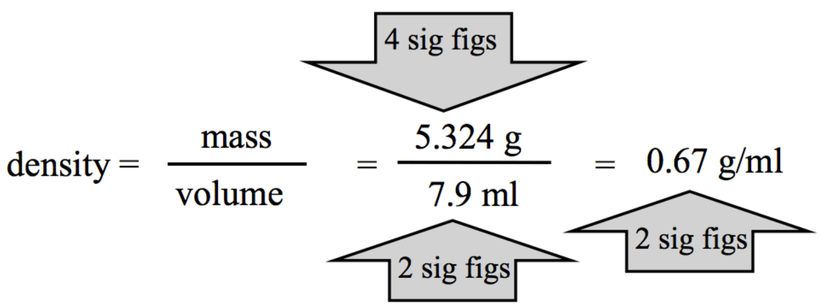
Calculations Involving Significant Figures

When doing ________________ ____ _________________with measured values, the answer should have *the same number of significant figures* as the measured value with the least number of significant figures.

When doing ________________ ____ _________________with measured values, the answer should have the same *precision* as the least precise measurement (value) used in the calculation.

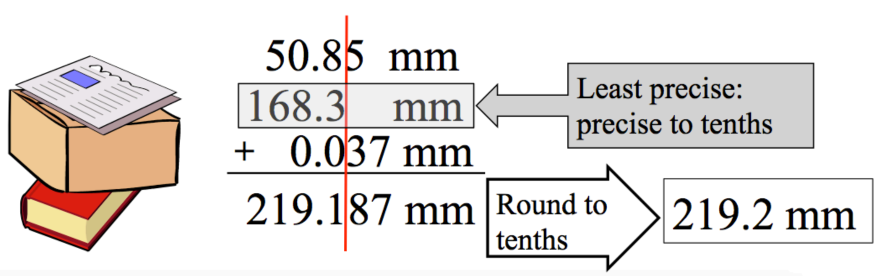
Example for Multiplication or Division:

- When doing ***multiplication or division*** with measured values, the answer should have ***the same number of significant figures*** as the measured value with the least number of significant figures.
- **Example:** If an object has a mass of 5.324 grams and a volume of 7.9 ml, what is its density?



Example for Addition or Subtraction:

- When doing ***addition or subtraction*** with measured values, the answer should have the same ***precision*** as the least precise measurement (number) used in the calculation.
- **Example:** A book 50.85 mm thick, a box 168.3 mm thick and a piece of paper 0.037 mm thick are stacked on top of each other. What is the height of the stack?



Understanding Check: Each of the numbers below is measured. Solve the calculations and give the correct number of significant figures.

a) 0.12 x 1.77
b) 690.4 ÷ 12
c) 5.444 – 0.44
d) 16.5 + 0.114 + 3.55

Unit Conversions

Typical Unit Conversion Problems:

- A package weighs 3.50 kg (kilograms), what is the weight in lbs. (pounds)
- A student is 60.0 inches tall, what is the student's height in cm?
- The temperature in Cabo San Lucas, Mexico is 30^{o}C, what is the temperature in ^{o}F?

To convert from one unit to another, we must know the __________________ between the two units of measure.

- Examples:
  - A package weighs 3.50 kg (kilograms), what is the weight in lbs. (pounds)
    - 1kg = 2.20 lb
  - A student is 60.0 inches tall, what is the student's height in cm?
    - 1 inch = 2.54 cm

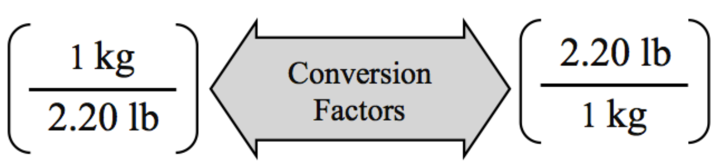
Unit Relationships to Know:

- 1 milliliter (mL) = 1 cubic centimeter (cm^3)
- 1 inch (in) = 2.54 centimeters (cm)
- 1 kilogram (kg) = 2.20 pounds (lb)
- 4.184 Joule (J) = 1 calorie (cal)

The *relationships* between units are called ______________________ _______________.

Unit Conversion Calculations: The Factor Label Method

A package weighs 3.50 kg (kilograms), what is the weight in lbs. (pounds)?
Equivalence statement: 1kg = 2.20 lb



Equivalence statements can be written as ________________ ______________.

Take notes here:

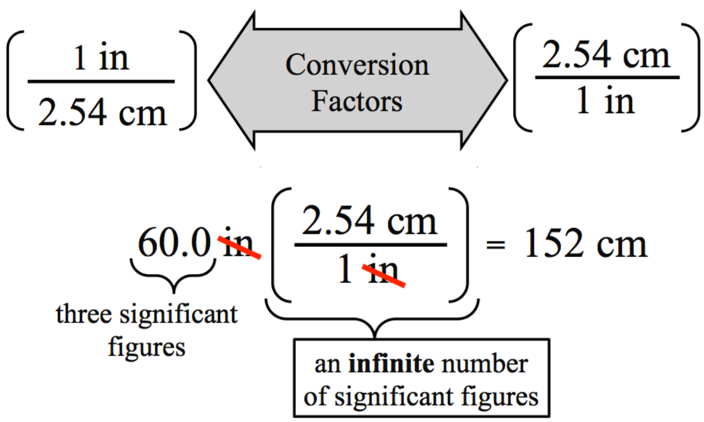
Some conversion factors have an ________________ number of significant figures.

__________ (**defined or agreed upon**) conversion factors have an ***infinite*** number of significant figures.

•Examples of exact/defined conversion factors
- 1 lb = 0.45359237 kg
- 1 inch = 2.54 cm
- 1 cg = 10^{-2}g
- 1 ft = 12 inches
- 1 ml = 1cm^3

A student is 60.0 inches tall, what is the student's height in cm?

Equivalence statement: 1 inch = 2.54 cm



Take notes here:

=

Understanding Check:

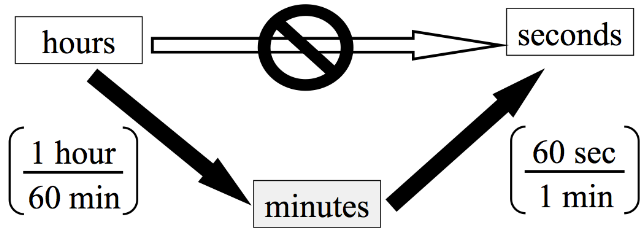
1) How many ft. (feet) in 379.3 in. (inches)?
   - 1 ft = 12 inches

2) How many eggs in 7.5 dozen?
   - 12 eggs = 1 dozen

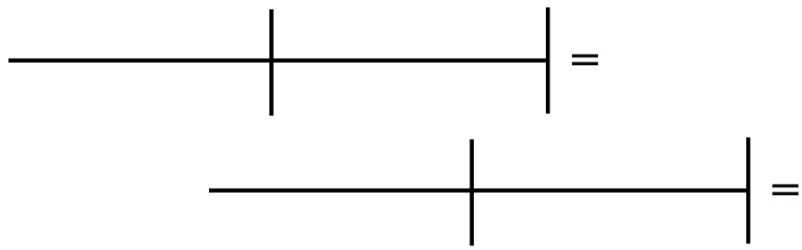
3) How many calories in 514 joules?
   - 1 calorie = 4.184 joules

Sometimes it takes more than one step!

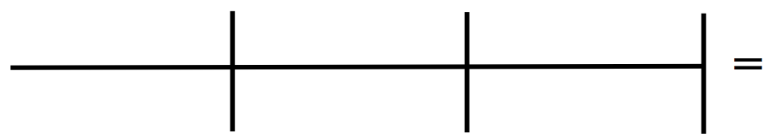
•Example: How many seconds in 33.0 hours?



Take notes here:



Take notes here:



Now you try a two-step conversion: How many inches in 5.5 meters given that:

- 1 inch = 2.54 cm
- 100 cm = 1 m

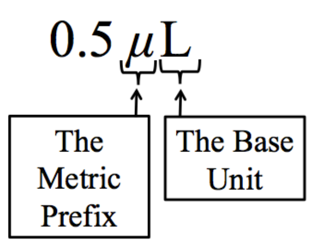
Metric Prefixes

Earlier, we used scientific notation to simplify working with very large or very small numbers.

Another way to simplify working with large or small numbers is to use metric ______________.

Example: The volume of blood required for diabetics to measure blood glucose levels in modern glucometers is about 0.0000005 L.

It is much more practical to use and say:



The metric **prefix** tells the ***fraction*** or ***multiple*** of the **base unit(s)**.

- For example, 1×10^6 µL = 1 L

The base unit can be ________________metric unit:

- liter (L), gram (g), meter (m), joule (J), second (s), calorie (cal)…etc.

Unit Conversions Within The Metric System

Example: The volume of blood required to measure blood glucose levels in modern glucometers is about 0.0000005 L.

- Question: How can we convert that to μL?
- Answer: We need the relationship between L and μL to get the conversion factor.

We will use the "Equality Table":

1 base unit =	
10 d (deci-)	0.1 da (deca-)
100 c (centi-)	.01 h (hecto)
1000 m (milli-)	.001 k (kilo)
1×10^6 μ (micro-)	1×10^{-6} M (mega-)
1×10^9 n (nano)	1×10^{-9} G (giga)

All these quantities in the table are equal; any pair can be used as a conversion factor!!!

Example: What is the relationship between L (microliters) and liters (L)?

1 base unit (Liters in this problem) =	
10 d (deci-)	0.1 da (deca-)
100 c (centi-)	.01 h (hecto)
1000 m (milli-)	.001 k (kilo)
1×10^6 μ (micro-)	1×10^{-6} M (mega-)
1×10^9 n (nano)	1×10^{-9} G (giga)

Equivalence statement: 1 L = 1×10^6 μL

This table works for **any** units!

The __________ ____________could be gram (g), meter (m), liter (L), joule (J), second (s), mole (mol), calorie (cal)… etc.

Understanding Check: Find the relationships between the following:

________ L = ________ mL

________ kg = ________ mg

________ nm = ________ m

________ cm = ________ mm

Example: How many μL (microliters) in 0.0000005 L?

$$\left(\frac{1 \times 10^6\ \mu L}{1\ L}\right) \quad \text{Conversion Factors} \quad \left(\frac{1\ L}{1 \times 10^6\ \mu L}\right)$$

Equivalence statement: $1\ L = 1 \times 10^6\ \mu L$

1 base unit (Liters in this problem) =	
10 d (deci-)	0.1 da (deca-)
100 c (centi-)	.01 h (hecto)
1000 m (milli-)	.001 k (kilo)
1×10^6 μ (micro-)	1×10^{-6} M (mega-)
1×10^9 n (nano)	1×10^{-9} G (giga)

Take notes here:

=

You try one: How many mL (milliliters) in 0.0345 (kL) kiloliters?

Equivalence statement: ______ mL = _______ kL

=

1 base unit (Liters in this problem) =	
10 d (deci-)	0.1 da (deca-)
100 c (centi-)	.01 h (hecto)
1000 m (milli-)	.001 k (kilo)
1×10^6 μ (micro-)	1×10^{-6} M (mega-)
1×10^9 n (nano)	1×10^{-9} G (giga)

You try another one: A vial contains 9758 mg of blood serum. Convert this into grams (g).

Equivalence statement: ____________ g = ____________ mg

Temperature Unit Conversions

$$°F = (1.8 \times °C) + 32$$

$$°C = \frac{(°F - 32)}{1.8}$$

$$K = °C + 273.15$$

- Note: The 273.15, 32, and 1.8 in the temperature conversion equations are *exact.*

When doing a calculation that involves **only** multiplication and/or division, you can do the entire calculation then round the answer to the correct number of significant figures at the end. The same is true for a calculation that involves **only** addition and/or subtraction. But what about a calculation that involves mixed operations: **both** multiplication or division ***and*** addition or subtraction?

When doing calculations that involve **both** multiplication or division ***and*** addition or subtraction, first do a calculation for the operation *shown in parenthesis* and round that value to the correct number of significant figures, **then** use the rounded number to carry out the next operation.

Example: On a warm summer day, the temperature reaches 85 °F. What is this temperature in °C?

The relationship between ^oF and ^oC is:

$$°C = \frac{(°F - 32)}{1.8}$$

First, we do the subtraction (operation in parenthesis) and round the calculated value to the correct number of significant figures based on the rule for addition/subtraction.

Next, we divide that rounded number by 1.8 (exactly 1.8 = 1.80000....) then round the calculated value to the correct number of significant figures using the rule for multiplication/division.

Take notes here: