METRICS AND MEASUREMENT

In the chemistry classroom and lab, the metric system of measurement is used, so it is important to know what you are measuring, and be able to convert from one unit to another.

The SI (Le Systeme International d'Unites) system of units is the internationally used system of metric units.

SI Base Units commonly used by Chemists		
Quantity (what are we measuring?)	**SI base unit**	**Symbol**
Length		m
Mass		kg
Temperature	kelvin	K
Time		s
Amount of substance	Mole (especially important in Chemistry! ***– see page 8 of these notes ☺)***	mol

All of the units listed above can be modified with the following prefixes. This tells you the magnitude of your measurement. You should be able to convert between all of these magnitudes (hint: go back to the base unit first!)

mega	kilo	hecto	deca	**Base Unit**	deci	centi	milli	micro
M	K	h	da	**gram (g)**	d	c	m	μ
1,000,000	1000	100	10	**meter (m)** **liter (L)** **mole (mol)**	0.1 or 1/10	0.01 or 1/100	0.001 or 1/1000	0.000001 or 1/1,000,000
10^6	10^3	10^2	10^1		10^{-1}	10^{-2}	10^{-3}	10^{-6}

FACTOR LABELING / DIMENSIONAL ANALYSIS

Example: 0.0342 g = _____ mg

1. Write the term to be converted- both the number and the unit

2. Write the conversion factor(s)

3. Make a fraction of the conversion fact such that
   a. if the unit in step 1 is in the numerator, the same unit in step 3 must be in the denominator.
   b. if the unit in step 1 is in the denominator, the same unit in step 3 must be in the numerator.

Since the numerator and the denominator are equal, the fraction must equal 1.

4. Multiply the term in step 1 by the fraction in step number 3. Since the fraction equals 1, you can multiply it without changing the size of the term.

5. Cancel units

6. Perform the indicated calculation and then round the answer to the correct number of significant figures.

Example:
120,000 mL = _____kL

Example:
Yasmine fills the tank of her new Jetta and sets off on a road trip. If she travels at 125 km / hr for three and a half hours, how far will she have gone?

SIGNIFICANT FIGURES

- the certain digits and the last, estimated, digit of a measurement
- reflect the precision of the measuring device and how carefully/precisely a measurement was made

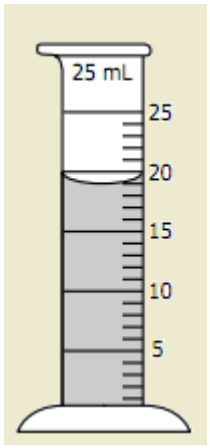
Atlantic – Pacific Rule
If a decimal is **p**resent, count from the ***Pacific*** side.
If a decimal is **a**bsent, count from the ***Atlantic*** side.
Start counting from the first nonzero digit you find, and count every digit (including zeros) thereafter!

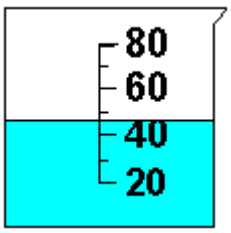
Examples:

Measurement	# of Significant Figures
5 mL	1
10.0 L	3
0.35 cm	2
120 km	2
6.55×10^{20} atoms	3

Practice a little:

Why Significant Figures?
Read the measurements below (assume all are in mL). Remember to estimate one digit past the smallest marking and ***circle the digit that you estimated!***

a. 

b. 

c. 

How many sig figs does each measurement have?

Now look at the following measurements. How many sig figs does each measurement have? Circle the estimated digit. What can you infer about the tool that was used?

Measurement (circle estimated digit)	How many sig figs?	What can you infer about the tool (what might the markings have looked like?)
6.23 m		
1.5 mL		
1021 kg		

…*now*…write 1-2 sentences explaining why you think we use significant figures:

_____
_____
_____
_____

…BUT…what if we do some calculations with our measurements?
In science numbers have units; they almost always refer to something that was measured in some way. And we can only trust our measurements so much (think about the quality of the tool you are using). So we need a way to keep track of that, even after we have done calculations.

Multiplication and Division Rule: limit and round to the least number of significant figures in any of the factors.

Example: 5.5 cm x 20.5 cm =

Addition and Subtraction Rule: limit and round your answer to the least number of decimal places in any of the numbers that make up your answer.

Example: 505 kg – 450.25 kg =

TOOLS IN CHEMISTRY

Below is a list of some measurement tools we use in Chemistry, as we discuss each one, please fill in its ideal use.

Measurement Tool	**When do we use it?**
Beaker	
Graduated Cylinder	
Erlenmeyer Flask	
Volumetric Flask	
Balance	
Thermometer	

PRECISION & ACCURACY *-careful measurements are critical in scientific investigations*

-
-

Causes of uncertainty:

a. Skill and care of the person making the measurement
b. Limitations of the measuring instrument

Accuracy =

Precision = a.

b.

Examples:

Data Set 1	Data Set 2
3.1 mL	2.9 mL
3.0 mL	3.4 mL
3.1 mL	2.6 mL

Percent Error - a measure of accuracy; how far the experimental or measured value is from the theoretical value

$$\text{Percent Error} = \frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}} \times 100 =$$

positive error: experimental value is too high compared to the theoretical value

negative error: experimental value is too low compared to the theoretical value

Using Data Sets 1 and 2 above, calculate the percent error for each (average each data set first), if the theoretical value is 3.0 mL.

As you're conducting an experiment, you must evaluate what factors in the procedure (and your execution of the procedure) contributed to your error.

DATA TABLES and GRAPHING

Below is a list of requirements and reminders for creating good data tables and graphs. Please refer to this when creating a data table or graph.

Using the example data below (for the effect of heating time on temperature of water), please construct a graph following the Graph Requirements. You should follow steps 1-8 and get a stamp from me when you are finished!

Data Table Requirements:

- Include a specific title
- Column for the MV, labeled with **units**
- Values of MV in order (usually increasing, or sequentially beginning to end)
- Column for the RV, labeled with **units**
- RV column subdivided for repeated trials (if relevant)
- Accuracy of data is appropriate to the measuring equipment being used
- Table is neat and presentable, with straight lines and clear writing (can be typed)

Sample table:

The effect of [INSERT YOUR MANIPULATED VALRIABLE] on [INSERT YOUR RESPONDING VALRIABLE]

Column for MV, labeled with units	Column for RV, labeled with units

For example:

The effect of heating time on temperature of water

Time on hot plate (s)	Temperature of water (°C)
60	36.5
120	55.3
180	76.8
240	95.8

Graph Requirements:

1. **Include a specific title** (for example, "Relationship between …,").
   - ★ On your graph (next page), write a title for the data in " *The effect of heating time on temperature of water"* data table.
2. Graph should be **½ page,** at a minimum
3. Graph axes must be straight, drawn with a ruler
4. Label your axes. The **MV is placed on the X axis** (horizontal line) and the **RV is placed on the Y axis** (vertical line). The unit of measurement is placed in parenthesis next to or beneath the variable.
   - ★ Correctly label the axes on your graph for the " *The effect of heating time on temperature of water"* data.
5. Determine the scales for the axes.
   i. First, round the lowest piece of data down and the highest piece of data up for each variable.
      i. **TIME**:
         1. lowest data rounds to: _____
         2. highest data rounds to: _____

ii. **AVERAGE TEMPERATURE:**:
    1. lowest data rounds to: _____
    2. highest data rounds to: _____

ii. Then, determine the range of these numbers, by subtracting the lowest number from the highest number.
    i. **Time range:** _____
    ii. **Average Temperature range**: _____

iii. Divide the range by the number of boxes on each axis. This final value equals the <u>increment</u> each box represents. You may <u>round up</u> to an appropriate number.
    i. **Number of boxes on X axis**: _____ **Increment**: _____
    ii. **Number of boxes on Y axis:** _____ **Increment**: _____

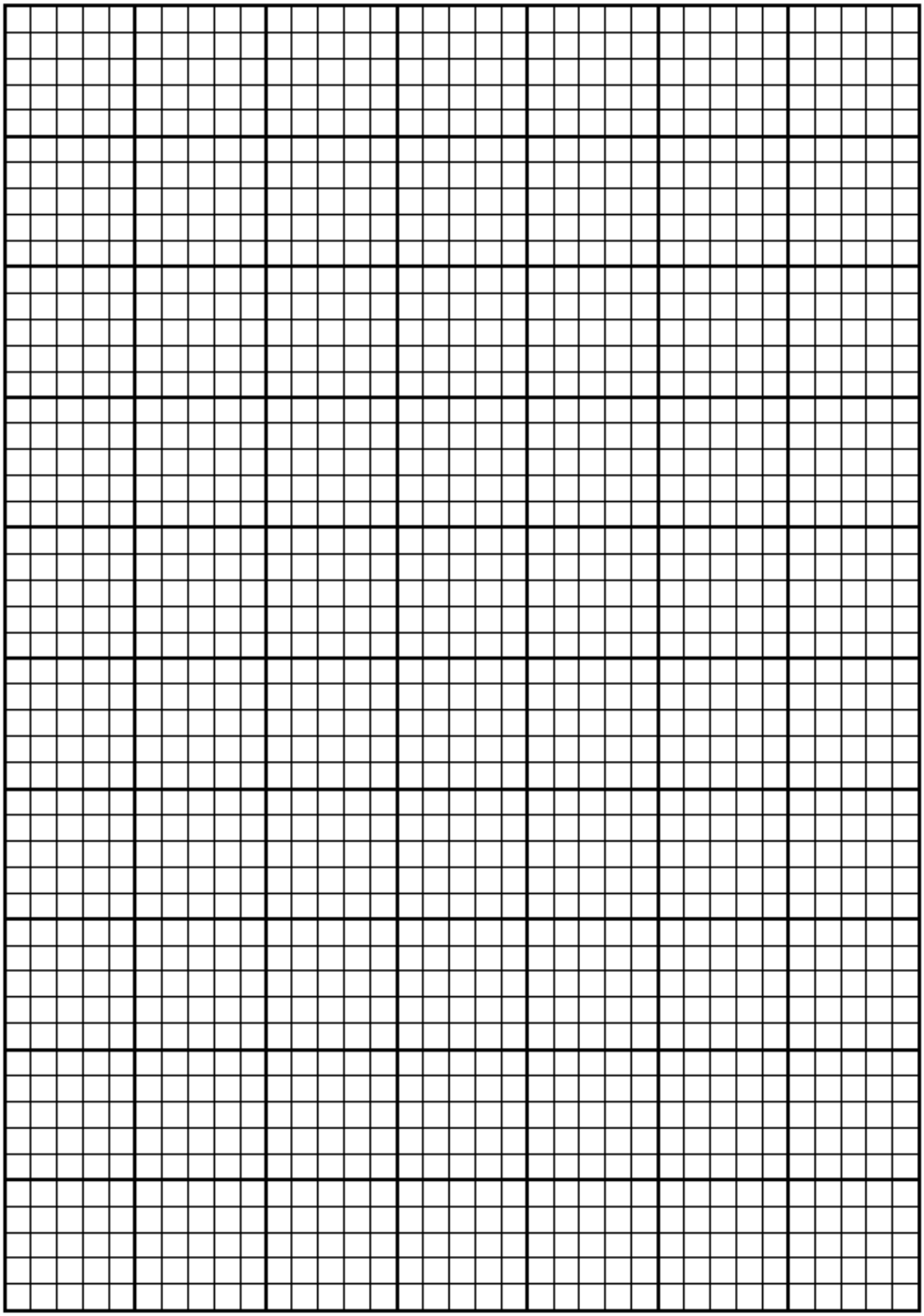
★ Label the axis on the graph with the increments determined in the previous step.

6. Plot data pairs
   ★ Plot the data found on "*The effect of heating time on temperature of water"* table
7. Draw a best fit line (remember, this is only <u>sometimes</u> appropriate…it is helpful for density, but unhelpful for heating curves when the phase changes…look at your data and DISCUSS if you are uncertain).
   The best-fit-line should have roughly equal numbers of data points above and below the line.
   The line must follow the pattern seen in data points
   The line does NOT have to start at the origin (0,0) ***<u>(think about whether this makes sense as a data point)</u>***
   ★ If you think it is appropriate (how did you decide?) draw a best-fit line, with a ruler, on your graph
8. Calculate the slope of your best fit line. Remember; we are calculating RISE over RUN
   i. First, pick <u>any two points</u> on the best fit line. The points you pick <u>do not have to be</u> actual data points. It is easier if you pick points that are located where two axis grid lines intersect.
   ii. For each point, determine its location along the X and Y axis.
       i. Point 1:
           1. Location on X axis (X_1): _____
           2. Location on Y axis (Y_1): _____
       ii. Point 2:
           1. Location on X axis (X_2): _____
           2. Location on Y axis (Y_2): _____
   iii. Plug your numbers into the following equation:

$$\text{Slope} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

   iv. Be sure your slope answer includes units! Your answer CAN BE a negative number!!

a) Calculate the slope of the graph here.
b) Write one sentence explaining what this slope means.
c) When done, get a stamp on your graph!



DENSITY

What is the equation for density?

What are the units for the density of water?

If you were to read the density of water from a graph, what would you expect the axes to be labeled?

Please write a sentence explaining what you think density means in generic terms.

MOLES

Moles are a unit used (especially in Chemistry) to express an "amount of stuff." Usually we are talking about moles of atoms, or moles of formula units or molecules, but we could just as easily be talking about moles of oranges or textbooks.
One mole (abbreviated mol) of something is just like a REALLY big dozen of something. A dozen donuts is 12 donuts. A mole of donuts is 6.02×10^{23} donuts (602,000,000,000,000,000,000,000)!
We will discuss moles in much more detail as the year goes on, especially in Stoichiometry, but for now you need to know that a mole is associated with 3 numbers.

1 mol = 6.02×10^{23} particles of something	(atoms, molecules, bicycles)
1 mol of gas at STP = 22.4 L of that gas	(that is, one mole of oxygen gas at Standard Temperature and Pressure takes up 22.4 liters of space)
1 mol = the mass from the periodic table	(for example, one mol of Carbon atoms have a mass of 12.01g)

Knowing that, please try these out:

a) 1 mol helium atoms = _____ helium atoms

b) 1.6 mol helium atoms = _____ helium atoms (think DIMENSIONAL ANALYSIS)

c) 2.3 mol helium at STP = _____ L helium

d) 3.4 mol helim = _____ g helium

e) 4.03×10^{24} carbon atoms = _____ mol carbon

f) 16.8 L oxygen gas at STP = _____ mol oxygen gas

g) 8.34 g lithium = _____ mol lithium

THE CLASSIFICATION OF MATTER FLOW CHART

Everything in the Universe is either…_____ or _____.

What is matter?

1.

2.

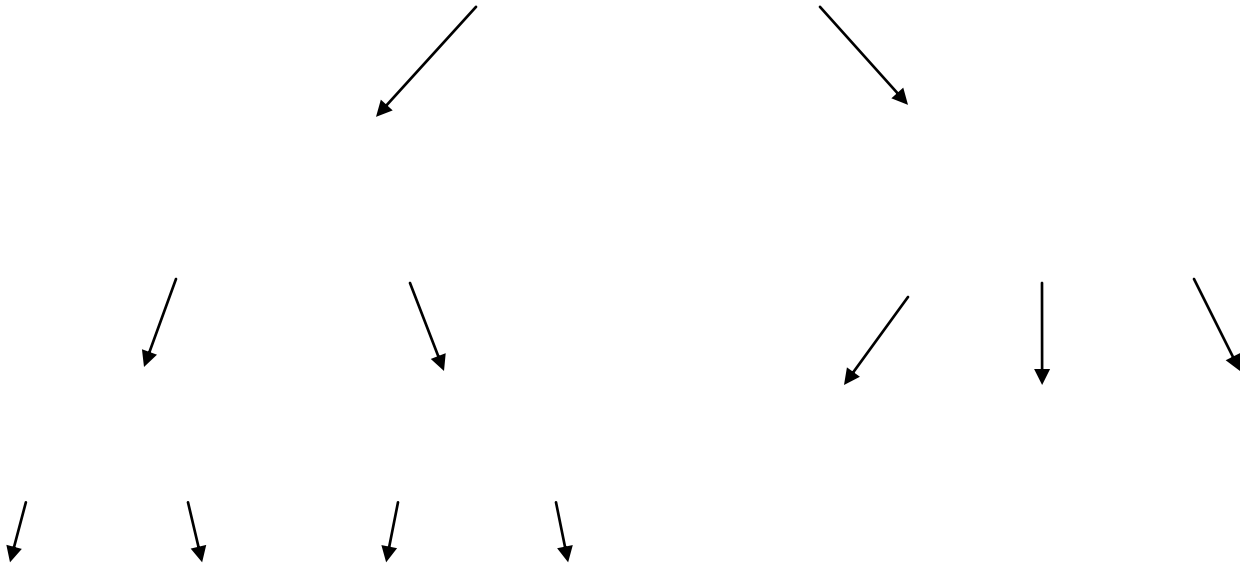
3.

-
-
-
- **aqueous**

4.

How do we describe matter?

How do we classify matter?



CLASSIFICATION OF MATTER

Classify each of the following as an element, compound, heterogeneous mixture, or homogeneous mixture.

water _____

carbon _____

air _____

table salt _____

sugar dissolved in water _____

homogenized milk _____

granite _____

oxygen _____

sand in water _____

Chocolate chip cookie _____

SEPARATION OF MIXTURES

Mixtures can be separated by *physical means*, this means we can separate the components of a mixture based on the different ways each component behaves physically. What state is it in at room temperature? How big are the pieces? At what temperature will it vaporize?

Here is a summary of some common separation techniques and what kind of mixtures we use them on.

Separation Technique	**Type of Mixture**	**How does the separation work?**
Filtration		
Evaporation		
Distillation		
Chromatography		