UNIT 1 Note Packet- INTRODUCTION TO CHEMISTRY Name: KEY

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	meter	m
Mass	kilogram	kg
Temperature	kelvin	K
Time	second	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)
   1g = 1000 mg

   $0.0342 g \,|\, \frac{1000 mg}{1 g} = 34.2 mg$
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.

3sf 3sf

$0.0342 g \,|\, \frac{1000 mg}{1 g} = 34.2 mg$

↑ fact → sf don't matter

1000 mL = 1 L   1000 L = 1 kL

Example:
120,000 mL = ______________kL

$\frac{120{,}000 \text{ mL}}{} \Big| \frac{1 \text{ L}}{1000 \text{ mL}} \Big| \frac{1 \text{ kL}}{1000 \text{ L}} = 0.12 \text{ kL}$

2 sf   2 sf

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?

$\frac{3.5 \text{ hr}}{} \Big| \frac{125 \text{ km}}{1 \text{ hr}} = 437.5 \text{ km} = 440 \text{ km}$

2 sf   2 sf

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 present, count from the *Pacific* side. →
If a decimal is absent, count from the *Atlantic* side. ←
Start counting from the first nonzero digit you find, and count every digit (including zeros) thereafter!

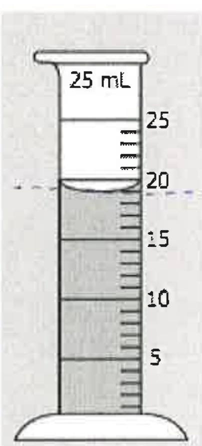
Examples:

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:

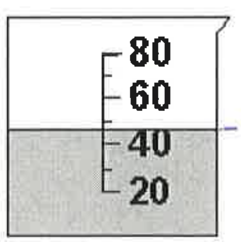
3000 → 1 sf   0.0026 → 2 sf 1.457×10^2 → 4 sf
3001 → 4 sf   1.0026 → 5 sf 8.9×10^{27} → 2 sf

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.


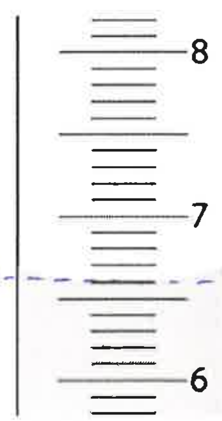
18.9 mL

3 sf

b.


47 mL

2 sf

c.


6.60 mL

3 sf

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	3sf	Closest markings were 0.1 m apart
15 mL	2 sf	closest markings were 1 mL apart
1021 kg	4sf	closest markings were 10 kg apart

...*now*...write 1-2 sentences explaining why you think we use significant figures:
To communicate how good your measuring tool is - helps explain how trustworthy (valid) your measurement is.

...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 = 112.75 cm² = 110 cm²
(2sf, 3sf → 2sf)

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 = 54.75 kg = 55 kg
(0 decimal places, 2 decimal places → 0 decimal places)

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	holding, ~~mi~~ mixing, heating solutions → not measuring
Graduated Cylinder	measuring ~~quantities~~ volume of liquids (solutions) → use one that is just bigger than you need
Erlenmeyer Flask	reacting or mixing solutions → not measuring
Balance	measuring the mass of something
Thermometer	measuring the temperature (average kinetic energy)

←

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

- No measurement can be absolutely certain.
- All measurements include a degree of uncertainty.

Causes of uncertainty:

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

Accuracy = how close a measurement is to the theoretical or true value

Precision = a. reproducibility or consistency
b. the degree of exactness or refinement of a measurement (an instrument with smaller increments will allow for a more precise measurement)

Examples:

	Data Set 1	Data Set 2	
high precision	3.1 mL	2.9 ~~3.1~~ mL	low precision
	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

published / "true" / accepted

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

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.

Data Set 1

avg = 3.07 mL

$$\% \text{ error} = \frac{\text{exp.} - \text{theo}}{\text{theo}} \times 100 = \frac{3.07 - 3.0}{3.0} = 2.3\%$$

too high

Data Set 2

avg = 2.97 mL

$$\% \text{ error} = \frac{2.97 - 3.0}{3.0} \times 100 = -1.1\%$$

too low

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 $\frac{1}{2}$ **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: 60 s
         2. highest data rounds to: 240 s

ii. **AVERAGE TEMPERATURE::**

1. lowest data rounds to: 35 °C
2. highest data rounds to: 100 °C

ii. Then, determine the range of these numbers, by subtracting the lowest number from the highest number.

i. **Time range:** 180s

ii. **Average Temperature range:** 65°C

iii. Divide the range by the number of boxes on each axis. This final value equals the increment each box represents. You may round up to an appropriate number.

i. **Number of boxes on X axis:** 35 **Increment:** 5.14 ~ 6s

ii. **Number of boxes on Y axis:** 50 **Increment:** 1.3 ~ 2 °C

★ 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 sometimes 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) ***(think about whether this makes sense as a data point)***

★ 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 any two points on the best fit line. The points you pick do not have to be 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): 72s
2. Location on Y axis (Y_1): 41°C

ii. Point 2:

1. Location on X axis (X_2): 174 s
2. Location on Y axis (Y_2): 73°C

iii. Plug your numbers into the following equation:

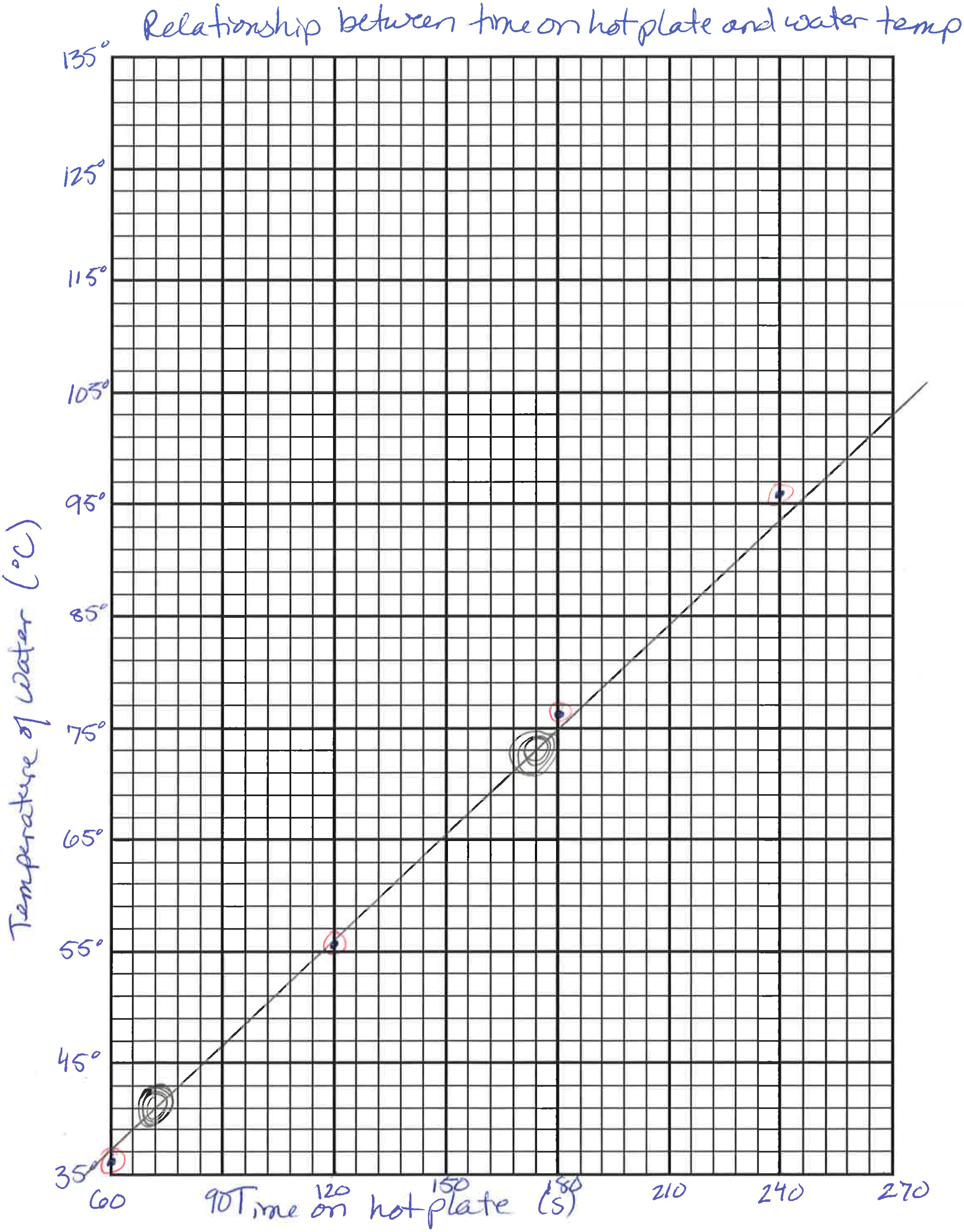
$$\text{Slope} = \frac{Y_2 - Y_1}{X_2 - X_1}$$

$$\text{slope} = \frac{73-41}{174-72} = \frac{32\,°C}{102\,s} = 0.31\ °C/s$$

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!

The water increased by 0.31°C for every second it was on the hot plate.

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

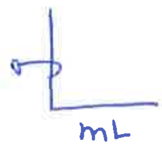

Relationship between time on hot plate and water temp.
135°
125°
115°
105°
95°
85°
75°
65°
55°
45°
35°
Temperature of Water (°C)
60
90
120
150
180
210
240
270
Time on hot plate (s)

DENSITY

What is the equation for density? $d = \frac{m}{V}$

What are the units for the density of water? g/cm³ or g/mL

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.

How much mass there is in a certain volume (how heavy something is for its size).

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 (pieces) (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) 0°C 1 atm

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 = 6.02×10^{23} helium atoms (1sf) — 1.6 mol He | 6.02×10^{23} He atoms / 1 mol He

b) 1.6 mol helium atoms = 9.6×10^{23} helium atoms (think DIMENSIONAL ANALYSIS) (2sf)

c) 2.3 mol helium at STP = 52 L helium (2sf) — 2.3 mol He | 22.4 L He / 1 mol He = 51.52 L He

d) 3.4 mol helium = 14 g helium (2sf) — 3.4 mol He | 4.01 g He / 1 mol He = 13.6 g He

e) 4.03×10^{24} carbon atoms = 6.69×10^{-2} mol carbon (3sf) — 4.03×10^{24} C atoms | 1 mol C / 6.02×10^{23}

f) 16.8 L oxygen gas at STP = 0.750 mol oxygen gas (3sf) — 16.8 L O_2 | 1 mol O_2 / 22.4 L O_2

g) 8.34 g lithium = 1.20 mol lithium (3sf)

8.34 g Li | 1 mol Li / 6.94 g Li =

THE CLASSIFICATION OF MATTER FLOW CHART

Everything in the Universe is either... matter or energy.

how much stuff

What is matter?

1. anything that has mass and volume ← how much space it takes up
2. made of atoms (basic units of matter), molecules or formula units (natural groups of atoms held together by bonds)
3. common states of matter
   - solid
   - liquid
   - gas
   - aqueous (currently dissolved in water)
4. matter, like energy, is neither created nor destroyed in any chemical process (law of conservation of matter)

How do we describe matter?

chemical properties
- what it does
- reactivity with... water, acid, base, oxygen, etc
- making a new substance (rearranging atoms)

physical properties
- what it is like by itself
- volume, color, density, melting point, boiling point, state

How do we classify matter?

pure substances: composed of one kind of atom, molecule, or formula unit

- elements (atoms) are the simplest pure substances (He, Au, Li, Pb, O_2)
  - single atoms
  - 2 diatomic elements → occur naturally in pairs → HONClBrIF
- compounds can also be pure substances
  - ionic compounds (ex. $NaCl$) (+, −) formula units
  - covalent compounds (ex. H_2O) molecules

mixtures: made up of multiple (2 or more) pure substances, physically mixed together

- heterogeneous: not evenly distributed
- homogeneous: evenly distributed
- colloid
- suspension: mixtures of 2 phases → settles in a centrifuge (it doesn't settle)

CLASSIFICATION OF MATTER

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

water compound | homogenized milk homogeneous
carbon element | granite heterogeneous
air homogeneous | oxygen element
table salt compound | sand in water heterogeneous
sugar dissolved in water homogneous | Chocolate chip cookie heterogneous

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	heterogeneous mixture one part bigger (solid than the other	the filter separates the big pieces from small, solid from liquid, etc.
Evaporation	• homogeneous mixture • aqueous solution (something dissolved in water) • want to keep solid	solution is heated, liquid evaporates, Solute remains
Distillation	• homogeneous mixture • 1 or more liquids with different boiling points • want to keep the liquid	• solution is heated, vapor is collected and recondensed • collect one liquid at a time
Chromatography	• homogneous mixture • 2 or more liquids or gases with different sizes	• mixture moves along the stationary phase, being separated by molecular size (and other factors like charge)