Volunteer Handbook

Conservation of Mass

October 2016

Student _____

UCSB Team Leader _____

Teacher _____ Period _____

DAY 1

As a volunteer for this module, keep in mind that you should not be doing the experiments in class! The students should be doing most/all of the work! You are here to help students and guide them through the experiments, but not do things for them. If students are really struggling with what to do, give them orders/responsibilities. We really want the students to get lots of hands-on experience and help them build self confidence in their ability to perform specific tasks!

Volunteer Introductions

Before the students go into their small groups, there will be a short introduction into what you will be doing that day. It will first start with introductions. Say a few words about yourself. Name, what year you are in school, why you are interested in science. Keep in mind that some students come from underprivileged backgrounds and don't have doctors for parents.

The lead volunteer should introduce the topic for this week's experiment. Tell the class that we are interested in mass. How do chemical reactions affect mass? We will be studying mass by carefully weighing reactants, performing reactions, then weighing the products. Give the students some perspective of what they will be doing this week. The lead will go through the idea of mass. Do I have mass? How do you think I can change my mass? Do if I start working out a lot, and I lose some of my mass, where does that go? Then go through the signs of a chemical reaction. Some of the different signs are change of state, color change, release of a gas, and many more. Tell the students to keep these in mind as they go through the experiments today. Then tell them the two experiments they will be doing: burning a marshmallow and burning steel wool. The students can then split into their small groups.

Chemical Reactions Review

A chemical reaction is a rearrangement of the atoms in an initial compound or compounds (the reactants) to form a new substance or substances (the products). Some examples are:

i)	synthesis	A	+	B	$\longrightarrow$	AB		
ii)	decomposition			AB	$\longrightarrow$	A	+	B
iii)	single-replacement	AB	+	C	$\longrightarrow$	AC	+	B
iv)	double-replacement	AB	+	CD	$\longrightarrow$	AC	+	BD
v)	carbohydrate combustion	CH_2O	+	O_2	$\longrightarrow$	CO_2	+	H_2O

A chemical reaction is usually accompanied by an observable physical change, such as a change in color and/or temperature, the emission of light, the evolution of a gas, or the formation of a precipitate. Reinforce this understanding by teaching the students to make **observations** of these perceivable changes.

The students in the class should be familiar with the terms "reactants" and "products," and should be able to draw basic chemical equations. They will NOT understand stoichiometry (moles) yet. They may also know one or two of the reactions above, however it is not likely they will know the exact terms for those reactions. If they are struggling with a reaction, write it down for them, and they may be able to recognize it.

Group Formation

The classroom will be arranged to have 5 groups of approximately 6 students each. You will pick a group and stick with it for the duration of the week.

Introduce yourself to your group again and ask the students to do the same. Learning their names is a great way to bond with your group. You will be with them for multiple days, so make sure you get to know them. Your group will also be very disappointed if you don't show up, so please try to be their everyday (or make arrangements with the program coordinator)

Comparative Demo Activity – Successively Challenging Student Knowledge

Overview

On Day 1, we will be using two demos to demonstrate chemical reactions, spark student observations and ultimately challenge their intellectual capabilities to test information that they are given. The first demo is designed to spark their interest observations and develop their knowledge to consider the **complete system** for these reactions beyond what is immediately obvious. In the first demo, mass is lost and the students must refer to the conservation of mass law to realize that they may be overlooking that gas is also a part of the system.

The second demo will further challenge the students' knowledge by stretching the limits of their understanding a step further – the students will observe an INCREASE in mass. Unlike demo one where the mass loss can be clearly explained with the formation of a gas product, for this demo they will have to consider that a gas is participating as a reactant.

When students are completing the conceptual questions on the back of the worksheets, encourage them to come up with hypotheses. Try to avoid answering their questions. Instead, *ask them* questions in order to foster their critical thinking!

DEMO 1 – Marshmallow Madness

Background Information

Marshmallows are made of fructose ($C_6H_{12}O_6$), sucrose ($C_{12}H_{22}O_{11}$), water (H_2O), and gelatin (a mixture of proteins). For our purposes, we will simplify the chemical reaction that occurs when burning marshmallows to the combustion of glucose:

$$C_6H_{12}O_6 + 3\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$$

For this reaction to occur, the marshmallow alone is not enough – you must also consider the oxygen in the room as a reactant. This will not be immediately clear to the students from the chemical formula alone. The end result of this demo is an apparent *loss* in mass, which does not agree with the Law of Conservation of Mass. The main goal is to have the students realize that gasses, either as reactants or products, should be considered when they are evaluating whether the total mass is conserved.

Instructions

- Distribute WORKSHEET 1. Have students fill out their name, period, and your name

- Tell the students that a reactant in this equation is glucose (but don't give them the full equation!). Ask some questions about what compounds they know of that could be formed from the atoms that make up glucose. The students have learned a little bit about photosynthesis, which is the reaction that makes glucose from water and carbon dioxide.

- Have the students make a hypothesis about whether the mass of the marshmallow after burning will be the same, less than, or greater than it was before it was burned. Ask them to justify their answers. (Maybe they could draw a picture of what they think will happen).

- Assist the students (if necessary) with lighting the marshmallow and making sure that it stays in the Petri dish. Make sure they are using the candle to light the marshmallow, NOT the lighter or matches.

- Help the students to write their observations. Ask if they think a chemical reaction is occurring, and how they know – encourage them to be descriptive!

- During the combustion, enforce safety and make sure that all the pieces of the marshmallow remain inside the Petri dish. After the flame has gone out, make sure that the students do not touch the Petri dish for at least two minutes. During this time, encourage them to continue making observations and discussing what they think happened.

- Once the final mass is recorded, help the students go through the questions on the back of the worksheet. When everyone has completed the final question, move on to DEMO 2.

DEMO 2 – Combustion of Steel Wool

Background Information

The chemical reaction under investigation here is the oxidation of iron:

$$4\ Fe + 3\ O_2 \longrightarrow 2\ Fe_2O_3$$

This experiment is in juxtaposition to the first demo – the system appears to *gain* mass when burned. This is because the product of this reaction is not a gas, and so all of it remains in the Petri dish. The students should try to formulate an idea as to how the two demos are related. Basically, the conclusion should be that the entire system needs to be accounted for, both on the reactant and on the product side of the equation. Sometimes a gas is formed during the reaction, sometimes a gas is used as a reactant. The total mass of the system should remain unchanged. At the end of the day, the students should start to form ideas of how they could design experiments to make sure that they account for all of the components of a chemical reaction, including gasses.

Instructions

- Distribute WORKSHEET 2. Fill out the information at the top.

- Follow essentially the same procedure as the last demo.

- Try to help the students come up with a “law” that applies to both of the demo systems. They’ll probably have trouble with this, but at least get them to list similarities and differences between the two.

- Sometimes, this demo does not work perfectly. Sometimes the steel wool loses weight, due to small errors in weighing. In this case, tell the students that the steel wool was actually supposed to lose mass, and ask them why they think that may have happened.

Wrap-up & Class Discussion

Once all the groups have finished the two demos, have them sit back in their seats. Ask them to explain what happened to the marshmallow when it was burned and how that differs from what happened to the steel wool when it was burned. Ask them if anyone can come up with a conclusion on what happens to the mass of something when it is burned. They shouldn’t be able to come up with a single rule because it depends on what is being burned.

Cleaning Duties

- ☐ Clean Petri dishes for next period
- ☐ Ensure all Demo kits are complete (restock marshmallows, steel wool, matches)
- ☐ Clean tongs (remove marshmallow residue where necessary)

DAY 1 Marshmallow Madness

Prediction	Justification
The marshmallow will lose mass when it is burned.	It usually shrinks when it is burned

Answers will vary. Encourage clear, definite predictions

Data Table

Mass of glass Petri dish	
Mass of Petri dish + marshmallow (before burning)	
Initial mass of marshmallow	
Mass of Petri dish + marshmallow (after burning)	
Final mass of marshmallow	
Change in mass of marshmallow	

(mass of marshmallow) − (mass of burned marshmallow)

Have the students come up with a way to calculate change in mass.

Observations

- Marshmallow changes color
- Smoke is given off
- There is a change in consistency of the marshmallow
- Heat is given off
- Marshmallow changes

1 Did a chemical reaction take place? What is your evidence?

yes. There was a color change (turned black)

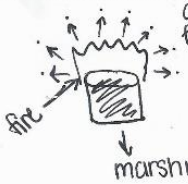
2 Was your prediction correct? Explain using evidence from the data collected.

yes. There was ___ grams lost when the marshmallow burned.

You are asking students to form a model to explain the loss of mass

3 Draw a model of the burning marshmallow to explain what is happening to the atoms during the reaction. Label all relevant parts visible and not visible.

Answers will vary



atoms are going from the marshmallow into the air. That's why the marshmallow becomes lighter

Note: Many students have not seen steel wool before. show them a piece so they can make a better prediction

DAY 1 Combustion of Steel Wool

Answers will vary

Prediction	Justification
The steel wool will lose mass when it is burned.	When things are burned (paper, wood, marshmallow), they usually lose mass

Data Table

Mass of glass Petri dish	
Mass of Petri dish + steel wool (before burning)	
Initial mass of steel wool	
Mass of Petri dish + steel wool (after burning)	
Final mass of steel wool	

Observations

Color change
Sparks given off
Smell

1 Did a chemical reaction take place? What is your evidence?

Yes, the steel wool changes color.

2 Was your prediction correct? Explain using evidence from the data collected.

No. The steel wool gained ___ grams.

n't dismiss ideas when students are acting models. guide them instead.

3 Draw a model of the burning steel wool to explain what is happening to the atoms during the reaction. Label all relevant parts visible and not visible.

The molecules from steel wool bond to ~~make the~~ molecules from fire and make the steel wool more massive.

Answers will vary. Make sure students are sharing their ideas with eachother

DAY 2

Overview of Today's Lab

Today the students will perform a precipitation reaction and measure the mass change (or lack thereof). The focus of today's lab is for the students to gain competence with their lab techniques and develop respect for precision, since these will directly affect their ability to obtain useful data. Particularly emphasize the importance of accounting for masses within the whole system and make them attentive to their technique. A discussion of sources of error is inevitable. There will also be a brief lecture on following directions. Keep in mind that although we are encouraging strict following of the procedure, we really want to nourish the students' critical thinking. Frequently ask students why they are performing a particular step in the procedure. Help them put it into the context of the overall experiment.

When the students first come into class, have a discussion about what was done previously. Remind them of the results of both the burning of the marshmallow and of the steel wool. Then tell them that we will be doing another experiment that is similar to those we did previously, but instead of burning something, we will be combining two chemicals to see what will happen to the mass when they are mixed.

Lab 1 – Mixing Copper Sulfate and Sodium Carbonate

Background Information

This experiment is a simple precipitation reaction designed to teach the students to work carefully with basic laboratory equipment and to think about which masses are important to measure. The chemical reaction is as follows:

$$Cu(SO_4)\ (aq) + Na_2CO_3\ (aq) \longrightarrow CuCO_3\ (s) + Na_2SO_4\ (aq)$$

The students will record the masses of their reactants, mix the two chemicals together, separate the solid product from the aqueous product, and then finally record the masses of those two separate products. The purpose of the experiment is to compare the initial mass of the reactants with the final mass of the products. Discussions about sources of error will help the students think about whether or not their initial and final masses are statistically the same, or if mass was actually lost/created in the reaction.

Instructions

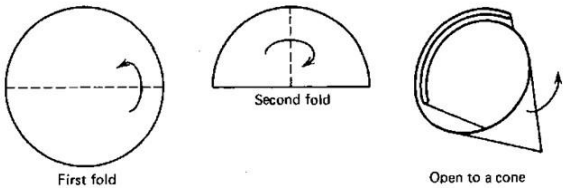
- Distribute the LAB 1 – Mixing Copper Sulfate & Sodium Carbonate packet. Give a very short overview of the today's experiment. E.g. "Today we are going to perform a precipitation reaction. The reactants will be two liquids, but the products are a liquid and a solid, which will be weighed separately."
- Before getting started, ask students if they know the proper names of the tools in front of them. Teach/remind them what an Erlenmeyer flask is, graduated cylinder, etc.

- Throughout the lab, make sure to encourage students to think about steps in which there is a potential loss of material. Enforce good lab practices. Frequently ask students why they are weighing a particular item to make sure they are following the procedure. There are two Erlenmeyer flasks for each group. Make sure you weigh the correct one!

- If the students are having trouble drying the graduated cylinder, crumple up a paper towel and stick it into the cylinder (pencils are good for this) to soak up stray bits of liquid.

- When the solutions are mixed, there should be an immediate formation of a blue, powdery precipitate. If this doesn't happen, make sure all the steps were followed exactly. If a thick, gel-like precipitate forms, the concentration of the copper solution is too high. Try diluting the solution with water if this is the case.

- When the precipitate forms ask the students what happened. E.g. "where did the solid come from? Where did its mass come from? Was the mass just created, or did it 'borrow' mass from the liquids?" Fold the filter paper as shown in the diagram:



- Filtering the solid will take several minutes to complete, and it will not fully dry. You can swirl the liquid in the funnel to speed the process up slightly, but be careful not to tear the filter paper.
- When removing the filter paper from the funnel, pinch opposite sides together and lift carefully. It might stick to the sides of the funnel, so don't pull away too quickly. Transfer the paper and solids to the weighing tray swiftly to avoid dripping any liquid.

- Make sure the students understand the calculations as they're doing them. They need to be able to repeat this procedure for tomorrow's lab without as much guidance.

- When finished with the data collection and calculations, help the students clean up their glassware and work stations so the next period can begin right away.

- Talk with the students about their "laws" and if they need to revise them. Ask if they can make any conclusions about the conservation of mass from their data, or if they think they had too much error to say anything definitive.

- Start a discussion with your students about today's lab and how it compares to the demos we did yesterday. What was similar? Color changes, phase changes, chemical reactions, etc. Lead them to realize that gas was unaccounted for on day 1!

Wrap-up & Class Discussion

You may have a quick discussion with the class, if there is time about what they did today. Ask them what happened to the mass overall. Remind them that even if their results were slightly off, the mass should have stayed the same. Since the reaction didn't take anything from the air around it, or give anything off, the mass shouldn't have changed. Start giving them the idea of the law of conservation of mass: that mass isn't created or destroyed.

Cleaning Duties

- ☐ Clean E. flasks for next period (hazardous waste containers will be in the classroom)
- ☐ Clean workstations and organize lab materials
- ☐ Replenish solutions and filter paper

DAY 3 Copper Sulfate & Sodium Carbonate

Table 1. Data Table for recorded masses.

Item to be measured	Mass in grams (g)	Observations
Mass of 20 mL $CuSO_4$ solution		Gel-like precipitate forms
Mass of 20 mL Na_2CO_3 solution		
Mass of empty 125 mL Erlenmeyer flask		
Mass of dry filter paper		
Mass of Erlenmeyer flask + liquids		
Mass of filter paper + solids		

Mass of $CuSO_4$ Solution		Mass of Na_2CO_3 Solution		Total Initial Mass
	+		=	

Mass of Erlenmeyer flask + liquids		Mass of empty Erlenmeyer flask		Mass of Liquids Collected
	−		=	

Mass of filter paper + solids		Mass of filter paper		Mass of Solids Collected
	−		=	

Mass of Liquids Collected		Mass of Solids Collected		Total Final Mass
	+		=	

TOTAL FINAL MASS		TOTAL INITIAL MASS		**CHANGE IN MASS**
	−		=	

Discussion

1 Why was it important to get all of the liquid out of the graduated cylinder in Step 3?

Because this could be a source of lost liquid.

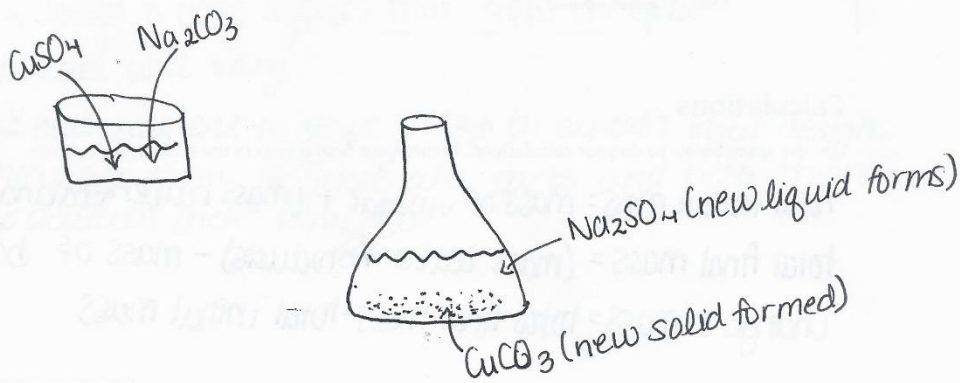
2 Is the **filter paper** part of the reaction? Why do we need to know its mass?

No, it just catches the precipitate that forms. We need to be able to subtract the mass of the filter paper from the total mass of the filter paper and precipitate.

3 Did a chemical reaction occur? What is your evidence?

Yes, a precipitate forms

4 Draw a model of this chemical reaction to explain what is happening to the atoms during the reaction. Label all relevant parts visible and not visible.



The molecules rearrange to form a new solid and a new liquid.

DAY 3

Overview of Today's Lab

Starting today, the students will increase their level of independent thinking to explore the "conservation of mass law" by measuring the total mass change in a new reaction. The students will be given a procedure for the experiment and then asked to improve their system based on their findings.

The activities will essentially repeat the procedure from Day 2, but with baking soda and vinegar instead of copper sulfate and sodium carbonate. Spoiler alert: this procedure will NOT work to prove the conservation of mass in this system – a net loss will be observed due to the formation of a gas. After they discover a net loss in mass, the students will begin to consider their accounting and develop a closed system to test their theory about mass conservation.

TED-Ed Talk – The Law of Conservation of Mass: *Todd Ramsey*

Watch the video at this URL: https://www.youtube.com/watch?v=2S6e11NBwiw
The teacher may choose to show this video the day before we come into the classroom. If this is the case, go straight into the next part of this experiment, mixing baking soda and vinegar. If this is not shown the day before, relate it back to the previous experiments. So if mass is neither created nor destroyed, what happened to the mass of the marshmallow and steel wool when we burned those? Then go into today's experiment. Tell the students that we will be mixing two chemicals together and seeing what will happen to the mass, just like we did the day before.

Lab 2 – Mixing Baking Soda & Vinegar

Background Information

This reaction, as you are well aware, generates a gas. If nothing is done to contain the gas, it will leave the system and the apparent mass will decrease.

$$NaHCO_3\ (s) + CH_3COOH\ (aq) \longrightarrow CO_2\ (g) + H_2O\ (\ell) + NaCH_3COO\ (aq)$$

The first step of the reaction produces carbonic acid (H_2CO_3) and sodium acetate. The carbonic acid spontaneously decomposes into water and carbon dioxide. The students are not expected to understand this full reaction, only that a gas is formed when the two reactants are mixed together.

This experiment is purposefully left open ended so that the students can begin to explore ways to contain and measure a gas. After the final calculation, it will be up to you and your group to decide in which direction to go. Try to keep the students interested and excited (not always easy).

Instructions

- Give a brief introduction (see Lab 2 worksheet).
- Make sure students write down their hypothesis before the reaction happens.
- After doing the calculations and observing a loss in mass, guide the students in a discussion about open and closed systems and how gasses must be included when considering conservation of mass.
- Pose the design challenge: create a closed system apparatus to observe conservation of mass in the baking soda and vinegar reaction.
- Encourage students to be creative and original during the brainstorming phase! Let them look through the available materials, but also tell them that if they come up with other materials for their design we can try to obtain them for the next day.

Make a list of possible materials that your students would like to use to build their gas-measurement apparatus and give it to the lead at the end of the period.

Wrap-up & Class Discussion

For the wrap up, have the students summarize what they did. Ask them what happened when the baking soda and vinegar were mixed. Then, ask them how they are going to stop the loss of mass. You want to hear closed system. They don't need to give out specifics.

Cleaning Duties

- ☐ Clean E. flasks for next period (the contents can be disposed of in the sink)
- ☐ Clean workstations and organize lab materials
- ☐ Replenish solutions and filter paper

DAY 4 Baking Soda & Vinegar

Prediction	Justification
Yes, the mass of the reactants will be equal to the mass of the products.	The molecules just rearrange and the mass stays the same.

Table 1. Data Table for recorded masses.

Item to be measured	Mass in grams (g)	Observations
Mass of 20 mL vinegar		As soon as the vinegar and baking soda come into contact, a gas is formed.
Mass of beaker		
Mass of beaker + baking soda		
Mass of beaker + products		

Calculations

Use the space below to do your calculations. Record your final results in the table at the bottom.

total initial mass = mass of vinegar + (mass beaker + baking soda - beaker)

total final mass = (mass beaker + products) - mass of beaker)

Change in mass = total final mass - total initial mass

Total Initial Mass (g)	
Total Final Mass (g)	
CHANGE IN MASS (g)	

Discussion

1 What was the change in mass? Include units!

The difference was ___ g.

2 Why did the mass change? How is this reaction different from the copper sulfate and the sodium carbonate reaction? Draw a model to show what is happening to the atoms in this reaction. Label all relevant parts visible and not visible. Provide evidence for your answer.

Mass was released in the form of gas.

No gas was formed in the copper sulfate + sodium carbonate reaction.

3 Is there a way to keep track of all the products in this reaction? How might you change the experiment? Your goal for today and tomorrow will be to design and test a closed system for this reaction. Sketch and label your design below.

Yes, design a closed system that traps the gas.

Answers will vary.

Ask each student in your group to explain their design. Encourage them to label all parts and help them articulate their thoughts.

DAY 4

Day 4 is a day of continued design and optimization for the Day 3 experiment. There is no need to give an introduction to what we will be doing today. Only remind them to make sure they stay on task and work efficiently. Continue with construction and testing of student designs. Engage with their reasoning and creativity. Students will be easily distracted by the commotion during this day, and they are particularly prone to playing around with the materials. Redirect their attention to the experiment! Don't be afraid to take materials away from them if they are just playing around aimlessly and not contributing to the project. Be authoritative when necessary. Certain materials should only be given to groups where you are certain that it will not be a distraction (ex. Play-dough).

Spend the first 10 minutes or so brainstorming while also letting the students start putting their materials together so they can get a feel for what will or will not work. If they are lacking creativity, subtly suggest ways to improve their design. Alternatively, put a material in front of them and tell them to include it as a part of their design.

As soon as the students seem to have a good idea of what they are doing, begin the trials! This should start no later than 20 minutes into class.

Students will probably start by weighing all the individual components of their system, before assembling it and initiating their reaction. This is okay, but time consuming. After they do this once (i.e. complete trial 1), ask them why they are weighing the individual items. What mass do they really need to know for their calculations? Initial mass of the closed system before the reaction. So could they just assemble their closed system and weigh the whole thing at once? Yes. Then they initiate their reaction, wait a few minutes for the reaction to go to completion, and weigh the whole thing again for a final mass.

Timing is going to be key for good results. If they have to add the ingredients, then seal up their container, some gas will escape. You might guide their thinking by asking them if the air in their setup is included in their mass. Is their system an open or closed one when weighing it for the initial mass? Ask if they could weigh everything as a closed system. They need to realize that the reactants must somehow be inside the closed system, but not yet reacting. Syringes are good for this. Or putting the baking soda inside the balloon or glove, sealing the system, then dumping the contents of the balloon/glove into vinegar whenever desired.

Make sure the students are doing the calculations while they go through the trials. Leaving all of the calculations to the end could cause problems. They may end up with a larger mass lost than expected, or the time it takes to calculate everything could take longer than expected. Additionally, make sure to check their calculations after they are done. Try to have them do it by hand, then check with the calculator on your phone. Many students struggle with simple addition and subtraction, so this is a good time for them to get some practice.

Start cleaning up 5 minutes before the period is over! Assign tasks for each student. Containers must be rinsed out and dried. Wipe down table surfaces. Return materials to the table up front, or dispose of them if suitable.

Volunteers, before leaving make sure that vinegar bottles are full and baking soda is readily available at each table. Make sure each table has the basic materials present (beaker, flask, graduated cylinder, scale, etc.).

DAY 5 Experiment Design Sheet

Chemists _____ Per _____ UCSB Leader _____

_____

_____

_____

Introduction *Write a brief statement describing the purpose of this experiment.*

The purpose of this experiment is to design a system that captures the gas so we can measure the mass of all the products.

Design Sketch *Draw how you will build your design. Label all materials.*

Answers will vary.

DAY 5

This is the final day for the students to finish their trials of the closed system they have designed. They should be able to get three trials total with their final design. It may be difficult to keep them interested and on topic during this day. As their group lead, it is your responsibility to make sure they stay on task. If time is running out, don't be afraid to take charge of your group. Don't do the work for them, just direct them so they know what they are supposed to be doing at all times.

Once they have all three trials done, they will find the average of their three trials. The students may not know how to find an average, so make sure to explain the concept of an average and why it is helpful to us. Let them know that an average is a way to explain a data set using one number. Also, make sure that they exclude any outliers. This is an important part of calculating the average and could throw off all of their calculations if outlier are included.

Also, make sure they know where their sources of error may have come from. Recognizing sources of error is an important part of the scientific process and is necessary for them to explain where any loss of mass may have gone. Some different sources of error may include:

- Spilled liquids
- Incorrect weighing
- Gases escaped
- Lost baking soda

After they have completed their averages, the students should start to complete their poster presentation. This is provided by the teachers and gives the students a way to wrap up their thoughts on the experiment. They are given the opportunity to state whether they think their experiment was a success (an experiment is considered successful if they have an average of 0.5 g or less lost) and how they would change it if they could. These presentations may take place the day that we are there if there is time, or they may take place the next day. Either way, make sure they have finished them before the end of class.