Are Chemical Reactions Closed Systems?

Measuring a Chemical Reaction

1. **Place about 100 ml of vinegar in a large plastic cup. Carefully weigh the cup AND the vinegar all together, and write down the total mass.** (Don't worry about subtracting the mass of the cup. It won't matter.)

   Mass of cup PLUS vinegar ____________ g.

2. **Carefully weigh about 1 teaspoon of baking soda. You should put the baking soda in a small plastic cup in order to weigh it, but first zero the balance with the empty cup on the balance before you weigh the baking soda. Write down the mass below:**

   Mass of baking soda ____________ g.

3. **How much would the cup of vinegar weigh if you added the baking soda to it** (but the vinegar did not react with the baking soda)**?**

   Total mass of the cup of vinegar plus the baking soda before the reaction _________ g.

4. **Slowly pour the baking soda into the large cup of vinegar. Just add a little at a time in order to ensure that the liquid does not bubble over the top of the cup.**

According to the chemical equation:

$$NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O + CO_2$$

$NaHCO_3$	$HC_2H_3O_2$	$NaC_2H_3O_2$	H_2O	CO_2
baking soda	acetic acid in vinegar	sodium acetate	water	carbon dioxide

What is happening inside the cup? Describe this below in your own words. Make sure you explain why the liquid is bubbling.

When the reaction is completely finished, weigh the cup and its contents again, and record the mass.

Mass of the cup and contents after the reaction ____________ g.

Complete the data table below by entering your data and by gathering data from your classmates.

Mass of baking soda	Total mass of cup and contents *before* the reaction	Mass of cup and contents *after* the reaction	How much mass was lost?	What is the ratio of the amount of mass lost divided by the mass of the baking soda?

5. **What patterns do you notice in the data table above? What might account for the pattern(s) that you observed?** (When you are finished generating a list here, turn to the next page.)

Counting Atoms in a Chemical Reaction

The mass that you just measured after the reaction is not the same as the amount that you calculated from before the reaction. Why not? What happened to the missing mass?

The mass of a single atom is very small. (For example, a one-gram piece of aluminum consists of about 22,000,000,000,000,000,000,000 = 2.2 x 1021 atoms of aluminum.) Since atomic masses are so very small, it is not convenient to measure them using the unit of grams. Instead, we use something else called an atomic mass unit (abbreviated as a.m.u.). In this unit of measurement, a hydrogen atom has a mass of 1 a.m.u. Below you will find a table of some common atoms along with their approximate masses as measured in a.m.u.

Atom	Mass in a.m.u.
Hydrogen (H)	1
Carbon (C)	12
Oxygen (O)	16
Sodium (Na)	23

The mass of one water molecule can be found with the use of this table in the following way:

Water (H20) has two hydrogen atoms and one oxygen atom.

Mass of H20 = 2 x (mass of H) + 1 x (mass of O)

= 2 x (1 a.m.u.) + 1 x (16 a.m.u.) = **18 a.m.u.**

Questions:

1. **Find the mass of each of the following:**
   Baking soda (NaHCO3)
   Acetic acid (HC2H3O2)
   Carbon dioxide (CO2)

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The reaction between baking soda and vinegar is written again below:

$$NaHCO_3 + HC_2H_3O_2 \rightarrow NaC_2H_3O_2 + H_2O + CO_2$$

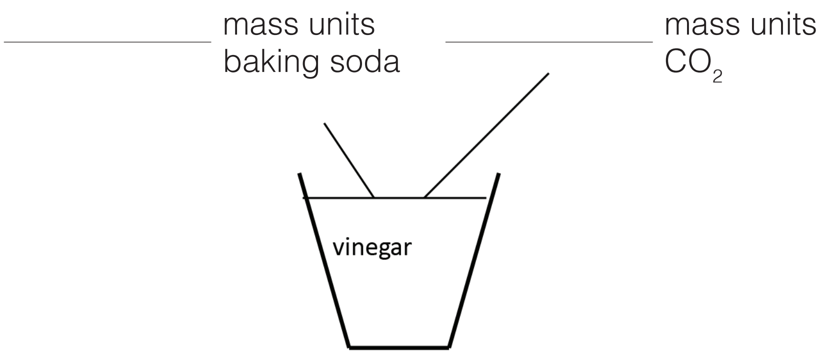
baking soda	acetic acid in vinegar	sodium acetate	water	carbon dioxide

This equation indicates that as a baking soda molecule and an acetic acid molecule react, one molecule of carbon dioxide gas is produced. **As this happens in your cup, what happens to the carbon dioxide gas that is formed? Where does it go?**

2. Suppose you could add one molecule of baking soda to your vinegar. Before the baking soda has time to react with the vinegar, by how much would the mass of your solution increase?

3. By how much will the mass of your solution decrease when a carbon dioxide molecule leaves the cup?

4. Fill in the blanks in this diagram using your answers to #2 and #3 above for two of the blanks.



5. What fraction of the original mass of the baking soda leaves the cup? (You can be approximate here.)

6. **What fraction of the original mass stays in the cup?** (You can be approximate here, too.)

7. **Use the predictions for mass change that you wrote above, but apply those predictions to a situation where you are considering measurable quantities—say gram quantities. If one gram of baking soda is added to a cup of vinegar and allowed to react, what mass change do you predict will occur?**

8. **Throughout this activity, we assumed that each particle—say baking soda or carbon dioxide--had a known mass and we could calculate this mass and make predictions based on these calculated masses. Using evidence from this experiment, how valid is this assumption?**