Lab Handout

Lab 4. Conservation of Mass

How Does the Total Mass of the Substances Formed as a Result of a Chemical Change Compare With the Total Mass of the Original Substances?

Introduction

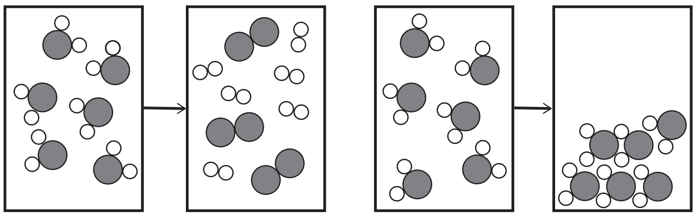
Matter is defined as anything that has mass and takes up space. Matter is composed of submicroscopic particles called atoms. To date, we know of 118 different types of atoms. All atoms share the same basic structure. At the center of an atom is a nucleus, which is composed of even smaller particles called protons and neutrons. Atoms are also composed of a third type of particle called electrons, which are found in specific regions around the nucleus. These regions are called orbitals. Scientists use the number of protons found in the nucleus of an atom to distinguish between the 118 different types of atoms. For example, there is 1 proton in the nucleus of a hydrogen atom and 30 protons in the nucleus of a zinc atom. Each type of atom also has a specific mass that reflects the composition of its nucleus.

Atoms can be bonded together in different combinations to create different types of molecules. Atoms or molecules can be combined to create different types of substances. A substance is a sample of matter that has a constant composition. Substances that consist of a single type of atom, such as gold or tin, are called elements. Substances that consist of a single type of molecule, such as water or sugar, are called compounds. A substance has qualities or attributes that distinguish it from other substances. These qualities or attributes are called physical and chemical properties. Physical properties are observable or measurable characteristics of a substance. Examples of physical properties include such things as density, melting point, and boiling point. Chemical properties, in contrast, describe how a substance interacts with other substances. For example, zinc reacts with hydrochloric acid but not with water. Scientists can identify a substance by examining its physical and chemical properties because every type of substance has a unique set of physical and chemical properties that reflect its unique atomic or molecular composition.

A substance can go through both chemical and physical changes. Any change in a substance that involves a rearrangement of how the atoms within that substance are bonded together is called a chemical change. A chemical change causes one or more substances to be transformed into one or more different substances. This process is often described as a chemical reaction. The original substance or substances involved in the chemical reaction are called reactants and the new substance or substances are called products. A physical change in matter, in contrast, does not involve a rearrangement of how the atoms within that substance are bonded together. A physical change is simply a change in the appearance of a substance. Examples of a physical change include a liquid turning into a solid or a solid turning into a liquid and a substance being broken or cut into smaller pieces. Figure L4.1 illustrates what happens at the submicroscopic level when a

FIGURE L4.1

Difference between a chemical change and physical change at the submicroscopic level



substance, such as water, goes through a chemical or physical change.

Many substances will react with other substances in predictable ways. Take the reaction of zinc and hydrochloric acid as an example. When zinc and hydrochloric acid are mixed together, the resulting products of the reaction will be hydrogen gas and a solution of zinc chloride. Another example is the reaction that takes place between a solution of silver nitrate and a solution of sodium chloride. When these two clear solutions are mixed together, the atoms in each substance interact and then rearrange to produce a different solution containing sodium nitrate and a solid substance called silver chloride. The properties of the products that are formed as a result of a chemical reaction are different than the properties of the reactants because the atoms in the original substances were broken apart and then rearranged and combined in a new way. The new configuration of atoms results in substances that have a different atomic or molecular composition. The unique atomic or molecular composition of a substance, as noted earlier, gives a substance its unique chemical and physical properties.

The chemical and physical properties of the reactants and the products of a chemical reaction are often very different even when the reactants and the products are composed of the same types of atoms. To illustrate, consider what happens when zinc (a metal) and hydrochloric acid (HCl molecules dissolved in water) are mixed. Zinc and hydrochloric acid, as noted earlier, react to produce hydrogen (a gas) and a solution of zinc chloride ($ZnCl_2$ molecules dissolved in water). Table L4.1 shows the composition of these four substances and some of the physical properties of each one. As can be seen in the table, zinc and hydrochloric acid (the reactants) have very different physical properties than hydrogen and zinc chloride (the products), even though the reactants and the products of this reaction are composed of the same three types of atoms.

TABLE L4.1

Formulas and some physical properties of zinc, hydrochloric acid, hydrogen, and zinc chloride

Substance	Formula	Physical properties			
		Density (g/cm³)	Phase (at 23°C)	Melting point (°C)	Boiling point (°C)
Zinc	Zn	7.14	Solid	419	907
Hydrochloric acid	HCl	1.2	Liquid	–26	48
Hydrogen	H_2	0.00009	Gas	–259	–253
Zinc chloride	$ZnCl_2$	2.9	Solid	290	732

At this point, we have established several fundamental ideas about the nature of matter. We know that all matter has mass, that matter is composed of atoms, and that each type of atom has a specific mass. We also know that the reactants and the products of a reaction contain the same types of atoms, because a chemical change is just a rearrangement of atoms. These fundamental ideas, when taken together, suggest that the total mass of the reactants should be the same as the total mass of the products left at the end of a chemical reaction. This claim, however, seems highly unlikely, because the substances that are left at the end of a reaction often have very different physical properties than the substances at the start of the reaction. Your goal for this investigation will be to test the validity or the acceptability of this hypothesis.

Your Task

Use what you to know about atoms, chemical reactions, systems, and how to track the movement of matter to design and carry out an investigation to determine if the total mass of the reactants is same as the total mass of the products left at the end of a chemical reaction.

The guiding question of this investigation is, **How does the total mass of the substances formed as a result of a chemical change compare with the total mass of the original substances?**

Materials

You may use any of the following materials during your investigation:

Consumables
- Sodium bicarbonate, $NaHCO_3$
- Magnesium (Mg) metal ribbon
- 1 M acetic acid, $C_2H_4O_2$
- 1 M hydrochloric acid, HCl
- 0.1 M aluminum nitrate, $Al(NO_3)_3$
- 0.1 M sodium hydroxide, NaOH
- 0.1 M copper(II) nitrate, $Cu(NO_3)_2$

Equipment
- 4 Beakers (various sizes)
- 4 Erlenmeyer flasks (various sizes)
- 2 5.0 ml Test tubes
- 4 Rubber stoppers
- 4 Balloons
- Weighing dishes or paper
- Electronic or triple beam balance
- Safety glasses or goggles
- Chemical-resistant apron
- Nonlatex gloves

Safety Precautions

Follow all normal lab safety rules. Acetic acid, hydrochloric acid, and sodium hydroxide are corrosive to eyes, skin, and other body tissues. Aluminum nitrate, copper(II) nitrate, and sodium hydroxide are toxic by ingestion. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

1. Follow safety precautions noted on safety data sheets for hazardous chemicals.

2. Wear sanitized indirectly vented chemical-splash goggles and chemical-resistant nonlatex gloves and aprons during lab setup, hands-on activity, and takedown.
3. Never put consumables in your mouth.
4. Clean up any spilled liquid immediately to avoid a slip or fall hazard.
5. Use caution when working with hazardous chemicals in this lab that are corrosive and/or toxic.
6. Handle all glassware with care.
7. Never return the consumables to stock bottles.
8. Follow proper procedure for disposal of chemicals and solutions.
9. Wash hands with soap and water after completing the lab activity.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will investigate four different chemical reactions. The reactants and products for each chemical reaction are provided in Table L4.2. Your goal is to determine if the total mass of the reactants that you use in each reaction is the same or different than the total mass of the products.

TABLE L4.2

Reactants and products of the four chemical reactions

Reaction	Reactants	Products
1	Sodium bicarbonate (s) and acetic acid (aq)	Carbon dioxide (g), sodium acetate (aq), and water (l)
2	Magnesium (s) and hydrochloric acid (aq)	Magnesium chloride (aq) and hydrogen (g)
3	Aluminum nitrate (aq) and sodium hydroxide (aq)	Aluminum hydroxide (s) and sodium nitrate (aq)
4	Copper(II) nitrate (aq) and sodium hydroxide (aq)	Copper hydroxide (s) and sodium nitrate (aq)

Note: aq = aqueous solution (solid dissolved in water); g = gas ; l = liquid; s = solid.

Some of products that you will produce during your investigation will be solids, some will be liquids, and some will be gases. Your challenge will be to find a way to ensure that none of the substances that you create when you mix the reactants together escape from the container you are using to hold them during the reaction or once the reaction is complete. You will only be given a limited amount of each reactant, so it is important to find a way to create a closed system before you mix any of the reactants together. You will also need to determine what type of data you need to collect, how you will collect it, and how you will analyze it before you begin your investigation.

To determine *what type of data you need to collect,* think about the following questions:

- What observations (color change, production of gas, etc.) will you need to make during your investigation?
- What measurements (mass of the reactants, mass of the containers, etc.) will you need to make during your investigation?

To determine *how you will collect the data,* think about the following questions:

- How will you ensure that none of the substances that you create when you mix the reactants together escape during the reaction or once the reaction is complete?
- How will you take into account the mass of the containers?
- When will you need to make your observations or measurements?
- What equipment will you need to collect the data?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine *how you will analyze the data,* think about the following questions:

- What type of calculations will you need to make?
- What type of table or graph could you create to help make sense of your data?
- How will you determine if the total mass of the reactants and the products is the same or different?

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

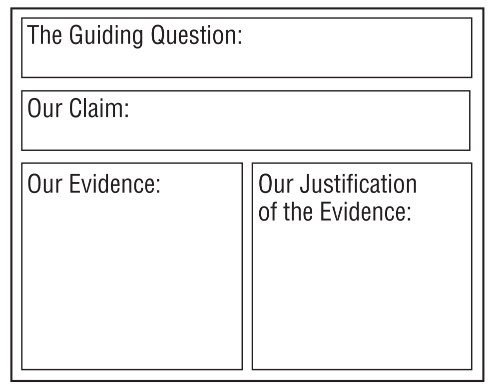
- the importance of defining a system under study;
- how scientists often need track how matter moves into, out of, and within a system;
- the difference between data and evidence in science; and
- how testing explanations requires imagination and creativity.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a *claim*, *evidence* to support your claim, and a *justification* of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L4.2.

FIGURE L4.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- How did you collect your data? Why did you use that method? Why did you collect those data?
- What did you do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- How did your group analyze the data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that way?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?

- How confident are you that your claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most acceptable and valid answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable and valid!