TOPIC

2.2

What happens to atoms in a chemical reaction?

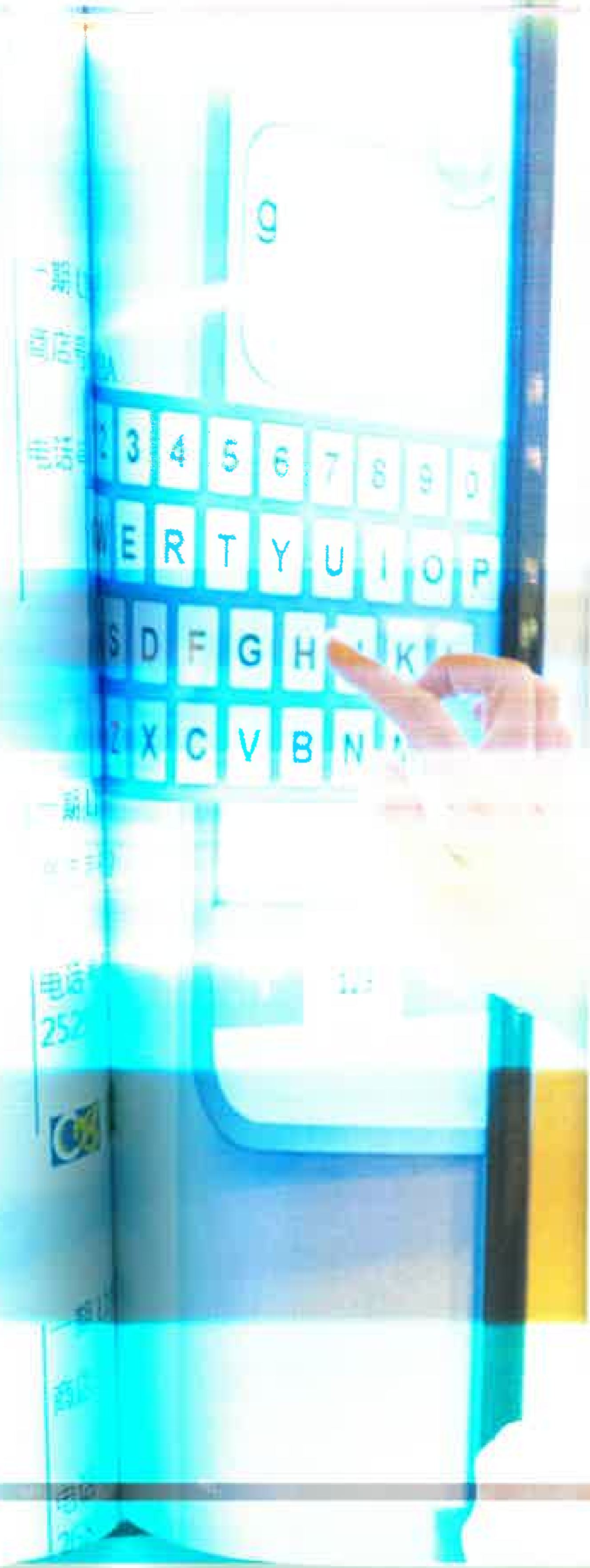
Key Concepts

- Atoms bond together to form ionic and covalent compounds.
- Bonds are broken, atoms are rearranged, and new bonds are formed.
- Mass cannot be created or destroyed in a chemical reaction.
- A chemical equation represents what happens to the atoms in a reaction.

Curricular Competencies

- Seek and analyze patterns, trends, and connections in data.
- Generate and introduce new or refined ideas when problem solving.
- Consider the role of scientists in innovation.

Touchscreens like this one and those used for smartphones and tablets are the result of chemical ingenuity that involves arranging atoms in a particular way to produce new material with desirable properties. These screens have been designed to withstand not only the force of objects being dropped on them, but also the impact of being dropped from a height. The toughened glass that makes up these screens is a synthetic glass-ceramic material. It shares the properties of both glass and ceramics, but is harder and stronger than each material on its own. Heating glass at very high temperatures provides some of the desired crystalline structure of ceramics, and replacing sodium ions with potassium ions chemically strengthens the glass.



1. **Identifying Preconceptions** What is a chemical bond? What are the different ways that atoms can chemically bond together? Give an example of each. Then describe how atoms of elements chemically combine.
2. **Evaluating** In making the synthetic glass described in the opening paragraph, potassium ions replace sodium ions in the spaces they occupy in the glass. As a result, the glass becomes compressed, which makes it much stronger. Why does switching from sodium ions to potassium ions cause the glass to become compressed?
3. **Considering First Peoples Perspectives** Balsamroot is a food of great importance to First Nations of the interior of BC. Balsamroot contains inulin, which is a carbohydrate people cannot digest, so raw balsamroot has little nutritional value. However, First Nations long ago understood how chemical changes could be applied to make the nutritional value of this energy-rich food source available to people. Find out what this understanding is.

There are 10 key terms that are highlighted in bold type in this topic:

- ionic compound
- ionic bond
- covalent compound
- covalent bond
- molecule
- law of conservation of mass
- chemical equation
- reactant
- product
- coefficient

Flip through the pages of this Topic to find these terms. Add them to your class Word Wall along with their meaning. Add other terms that you think are important and want to remember.

CONCEPT 1

Atoms bond together to form ionic and covalent compounds.

Activity

Finding Compounds

Your teacher will provide your group with cards that have a chemical name or formula of an ionic or covalent compound and its properties. Look around the classroom, and identify where each compound is. The compound may be part of a material or exist on its own. State which compounds are ionic and which are covalent. Explain how you decided.

Chemical reactions involve one or more pure substances interacting to form a different substance or substances. These pure substances can be elements or compounds. Compounds are made of atoms of different elements that chemically combine in specific proportions. They are classified into one of two categories, ionic or covalent, based on the type of chemical bond that forms between the atoms.

Ionic Compounds

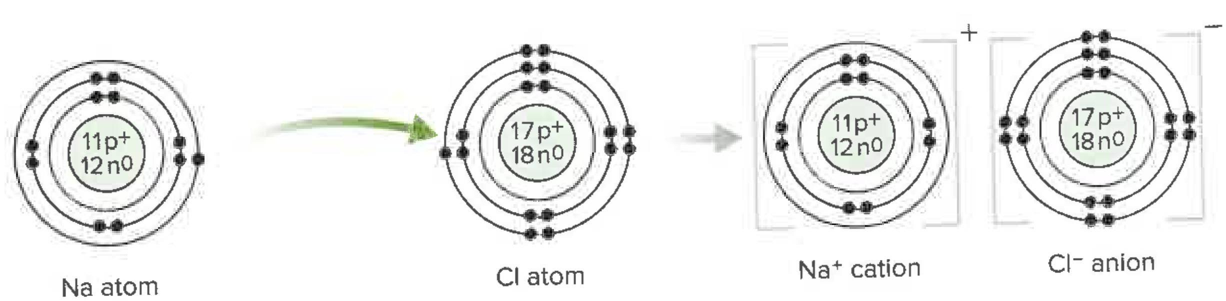
Ionic compounds consist of positively charged ions, called *cations*, and negatively charged ions, called *anions*. These ions are held together by **ionic bonds**. In binary ionic compounds, atoms of a metal element lose one or more electrons to atoms of a non-metal element (**Figure 2.4**). There is an *electrostatic attraction* between the cations and anions, resulting in the ionic bond. The strength of that attraction, and the resulting ionic bond, depend on the types of ions involved.

In the formation of ionic compounds, the electron transfer results in ions that have full valence shells and, therefore, greater stability.

ionic compound a compound made of oppositely charged ions

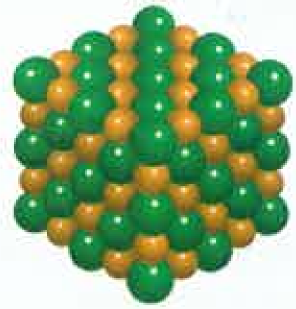
ionic bond a strong attraction that forms between oppositely charged ions

Figure 2.4 In binary ionic compounds such as sodium chloride, the transfer of electrons from metal atoms to non-metal atoms produces ions that are strongly attracted to each other. **Processing: What is the chemical formula for sodium chloride? Explain why sodium ions and chloride ions have the charges that they do.**



Activity

Predicting and Visualizing Ionic Compounds



1. Sodium chloride exists as a cubic crystal lattice.

   Describe how ions in sodium chloride are arranged in the crystal lattice. The chemical formula for an ionic compound represents the *formula unit*, which is the smallest whole number ratio of positive and negative ions to form a neutral compound. What is the formula unit of sodium chloride?

2. Give the names and chemical formulas for the ionic compounds that will form from the following pairs of elements. Why does each element form the ion it does? How many bonds form in each formula unit?

   a) calcium and oxygen
   b) sodium and fluorine
   c) aluminum and sulfur
   d) potassium and bromine

3. Choose one of the above compounds. Find out how its ions are arranged in a crystal lattice, and build a three-dimensional model using materials supplied by your teacher. Work with other students to evaluate the models.

Covalent Compounds

Covalent compounds consist of atoms of two or more non-metal elements joined together by **covalent bonds**. A covalent bond is a strong attraction between atoms that forms when the two atoms share electrons. The sharing of electrons results in electrostatic attractions between the positive nucleus of each atom and the negative electrons of the atoms.

As with ionic compounds, the formation of a covalent compound results in an increase in stability of the atoms due to the filling of valance shells. However, non-metals in covalent compounds achieve a full valence shell by sharing electrons.

In water, the single valence electron of each hydrogen atom is paired with one of the valence electrons of oxygen. The sharing of this electron pair forms a single covalent bond. Covalent compounds can also contain double bonds, which form when atoms share two pairs of electrons, and triple bonds, which form when atoms share three pairs of electrons (Figure 2.5).

covalent compound a compound that results when atoms of two or more elements bond covalently

covalent bond a strong attraction between atoms that forms when atoms share valence electrons

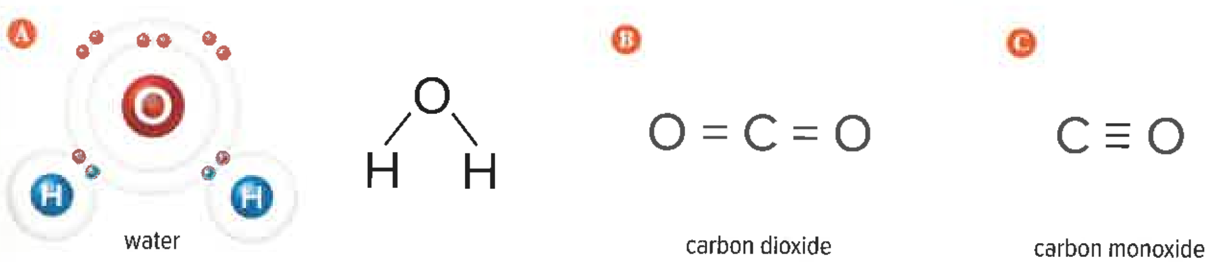


Figure 2.5 (A) In water, oxygen forms a covalent bond with each hydrogen atom. Single bonds may be represented with a single line. (B) Double bonds are shown using two parallel lines. (C) Triple bonds are shown using three parallel lines.

molecule a particle made up of two or more atoms bonded by covalent bonds

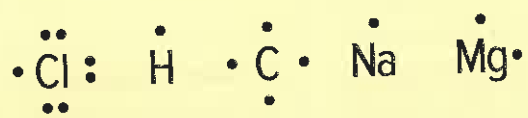
Most covalent compounds exist as molecules. A **molecule** is the smallest independent unit of a covalent compound. In a glass of water, individual molecules of water exist. In contrast, sodium chloride exists as a continuous arrangement of ions, not as separate molecules.

Two or more atoms of the same element that are joined by a covalent bond are also molecules. These elements include H_2, N_2, O_2, Cl_2, Br_2, I_2, F_2, S_8, and P_4. However, these molecules are not compounds, because they contain only one element.

Extending the Connections

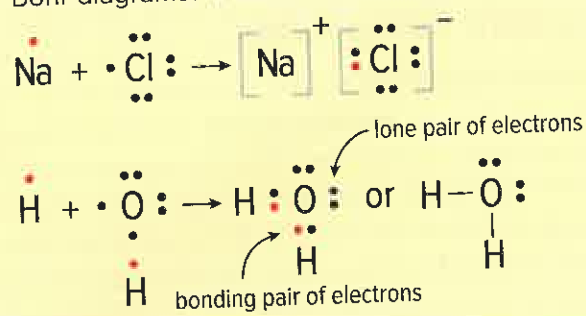
Lewis Diagrams

A common way to model electrons in an atom and the arrangement of atoms in a molecule or formula unit is with Lewis diagrams. They show only the valence electrons. Lewis diagrams consist of an element's chemical symbol surrounded by dots that represent its valence electrons. For helium, the dots are paired. Starting with second-period elements, dots are placed singly around the symbol at the points of a compass until the fifth one.



Then they are paired. In Lewis diagrams for molecules, each bonding pair of electrons is represented with a single line. Lewis diagrams that represent bonding in sodium chloride and water are shown below.

Draw the Lewis diagram for Cl_2. What is an advantage to using Lewis diagrams instead of Bohr diagrams? What is a limitation?



Activity

Showing the Bonds

1. Name each of the following substances. Which is different from the others? Which should be classified as molecules? Which should not?

   $MgBr_2$, CCl_4, KI, F_2

2. Use Bohr diagrams or Lewis diagrams to show how ionic or covalent bonds form in each substance. How many bonds does each molecule or formula unit have?
3. Use materials provided by your teacher to build a three-dimensional model of CCl_4. What type of compound is it? How does it compare with the model of NaCl you made?

Before you leave this page . . .

1. What type of bond is formed between two non-metal atoms? Describe how it forms.
2. Describe how a binary compound composed of sodium and bromine forms.

CONCEPT 2

Bonds are broken, atoms are rearranged, and new bonds are formed.

Activity

Rearranging the Atoms

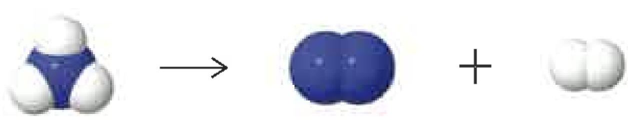
CAUTION: Avoid touching the burner directly while hot. Following your teacher's instructions, light a Bunsen burner. Methane, CH_4, is the covalent compound in natural gas that burns in the presence of oxygen, O_2, to produce the flame that you see. In this reaction, carbon dioxide gas and water vapour form.

1. Where does the oxygen come from? Where are the products that form?
2. Using the materials provided by your teacher, build models of the four chemicals that show individual atoms and bonds between the atoms.
3. Describe how the atoms in molecules of methane and oxygen are rearranged to form the products. (Keep your models to use in other activities.)

When thinking about chemical reactions, imagine the atoms of each substance and how they might need to move for the reaction to take place. Some examples are shown in **Figure 2.6**.

Elements can interact to form compounds.

Compounds can break apart to form elements.



Elements and compounds can interact to form new compounds.

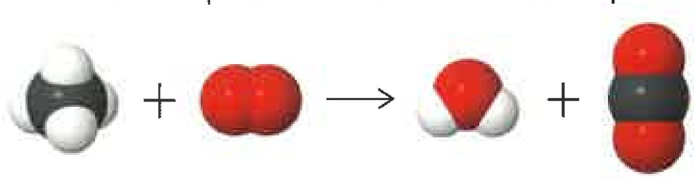


Figure 2.6 Examples of ways that elements and compounds can form new substances in chemical reactions. **Analyzing: What is happening to the atoms and bonds?**

Chemical Bonds and Energy

In order for atoms to be rearranged in a chemical reaction, the chemical bonds that hold them together must first be broken. Then new bonds can form between different atoms to produce different substances. For all chemical reactions, changes in energy are involved in these processes.

Chemical bonds are electrostatic attractions that hold atoms or ions together (**Figure 2.7**). In order to break those bonds (attractions), energy must be added until the atoms or ions are no longer held together. The amount of energy that is needed to break a chemical bond depends on the atoms or ions involved.

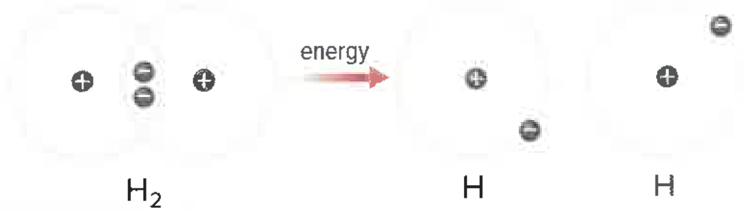


Figure 2.7 Energy must be added to break a chemical bond. **Applying: Is the bond shown here covalent or ionic? How do you know?**

When a chemical bond forms, energy is released. When chemical bonds form and the atoms achieve full valence shells of electrons, the atoms gain stability. Thus, atoms go from low stability (high energy state) to greater stability (lower energy state), and the "extra" energy is released (**Figure 2.8**).

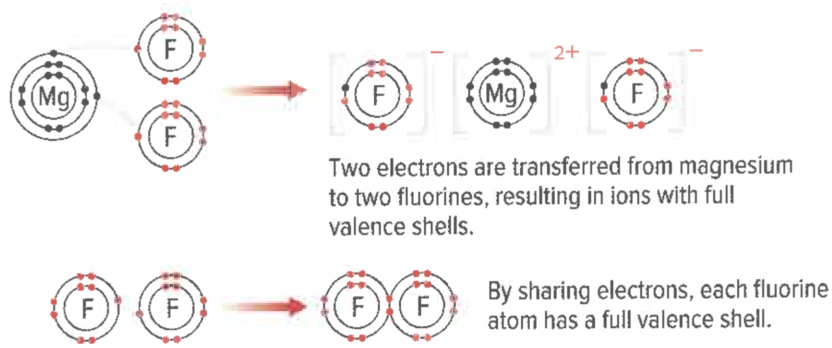


Figure 2.8 When a bond forms, energy is released.

Activity

Making and Breaking the Bonds

Look at your models for the reaction of methane with oxygen to produce carbon dioxide and water. What happens in the reaction in terms of the bonds that are broken and new bonds that must form? Which would require energy and which would release energy? (Keep your models to use in other activities.)

Before you leave this page . . .

1. Is it possible for a chemical reaction to occur without new chemical bonds forming? Explain.
2. Describe how energy is involved in making and breaking chemical bonds.

CONCEPT 3

Mass cannot be created or destroyed in a chemical reaction.

In the late 1700s, a French chemist named Antoine Lavoisier, shown in **Figure 2.9**, greatly advanced the understanding of chemical reactions. He recognized that accurate inferences could be made about what happens to substances in a chemical reaction by studying the masses of those substances. Many experiments were performed that involved measuring the mass of the substances before the reaction, performing the reaction in a sealed container, called a *closed system* (**Figure 2.10**), and then carefully measuring the mass of the substances after the reaction.

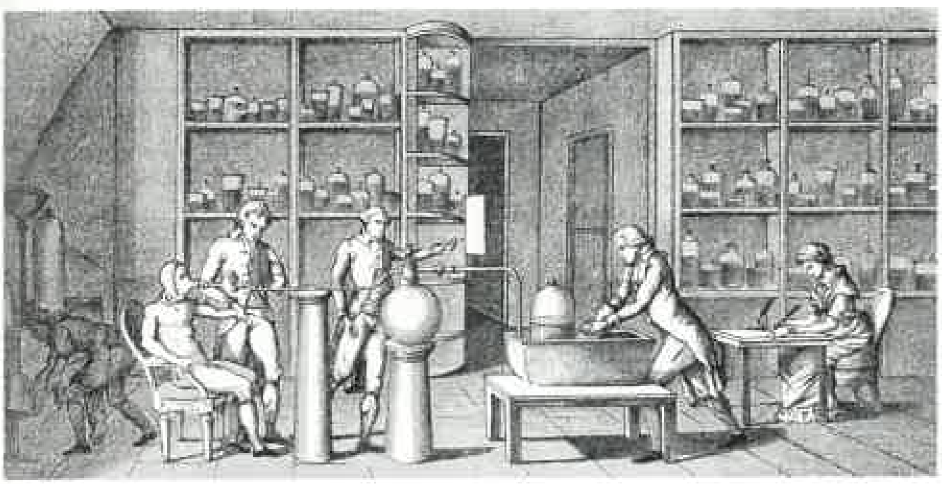


Figure 2.9 Antoine and Marie-Anne Lavoisier were a successful scientific team. Marie-Anne translated scientific papers from English into French for her husband and drew diagrams of the equipment he used for his experiments. **Analyzing: What is going on in this image? What equipment do you recognize? What kind of experiment do you think is taking place?**

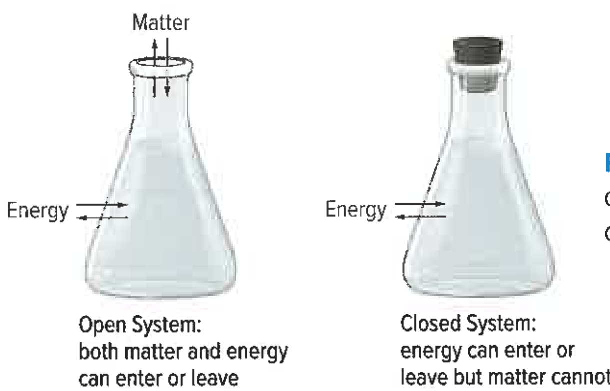


Figure 2.10 Reactions can occur in open or closed systems.

Extending the Connections

Women in Chemistry and Other Sciences

Margaret Cavendish published ideas about atoms and energy in the late 1600s. Elizabeth Fulhame was a chemist reknowned for her meticulous experimental methods during the late 1700s. You likely have never heard of either. Why do we know so much less, and often so little, about women in science until more recent times? Who should we know more about?

Showing the Conservation of Mass

One experiment that Lavoisier studied extensively involved mercury(II) oxide, HgO. This compound is a red solid that breaks down to form silver-coloured liquid mercury, Hg, and colourless oxygen gas, O_2, when it is heated. Figure 2.11 shows the kind of apparatus Lavoisier used in his experiments with mercury(II) oxide.

He repeated this reaction many times, and each time the results were the same: the total mass of the mercury(II) oxide was the same as the total mass of the mercury and oxygen that were produced. Therefore, whatever atoms are present in the substances undergoing a chemical reaction must also be present in the new substances that form. This observation is summarized in the **law of conservation of mass**.

law of conservation of mass in a chemical reaction, the total mass of the substances used is equal to the total mass of the substances produced

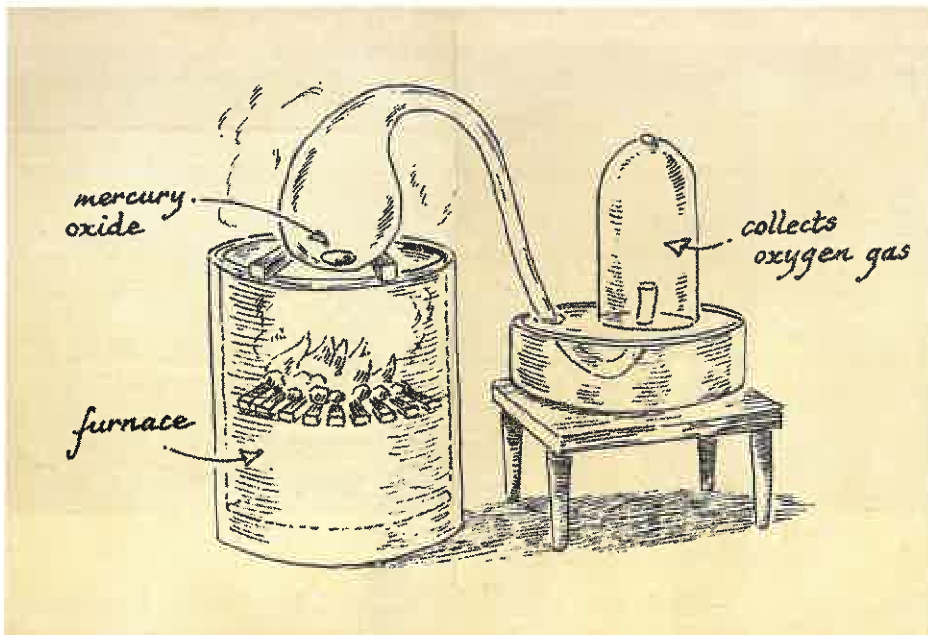


Figure 2.11 This sketch shows the apparatus that Lavoisier used for his experiment with HgO. **Communicating: Is this setup a closed or open system? How can you tell?**

Connect to Investigation 2-C on page 136

Activity

Modelling Conservation of Mass

Working with a partner, use your models of methane, oxygen, carbon dioxide, and water to show what must happen in order for the reaction to obey the law of conservation of mass. How many models of each type of molecule did you need to use in order to demonstrate the law of conservation of mass? Explain your answer.

Before you leave this page . . .

1. What is the law of conservation of mass?
2. What is the difference between an open and closed system?
3. What would you expect Lavoisier's results to be if he had used an open system? Explain your answer.

TAKE a Stand

Make a Difference

What does the law of conservation of mass tell us about waste?

The law of conservation of mass has important implications for society and the environment. New air, water, chemicals, and other material natural resources cannot be produced or removed by any use of science or technology. All the matter that exists on Earth, now, is all the matter that ever existed and ever will exist since the universe formed. We can extract substances from the environment and change them into other useful substances, but we cannot make matter where it did not already exist. In the same way, we can bury our waste materials in the ground, dump them in waterways, or send them into the air as incineration smoke, but the matter of which those materials were made is still here. In nature, matter can only be endlessly recycled.

Analyze and Evaluate

1. Wastes may be classified in terms of their potential danger (hazardous vs. non-hazardous) as well as their source (residential, municipal, agricultural, industrial). In what ways is it useful to classify wastes in these or other ways? Is it possible that the act of classifying wastes creates a false sense of security? Discuss your ideas.
2. How is reducing waste different from recycling it? Why is this distinction important?

Apply and Innovate

3. Take a stand about a chemical waste you are aware of. What can be done to reduce it and its impact on the environment? How can you inform the public and what can you do to encourage changes in thinking and behaviour? Develop a strategy using the conservation of mass as a basis for your argument.

CONCEPT 4

A chemical equation represents what happens to the atoms in a reaction.

Activity

Paper Clip Equation

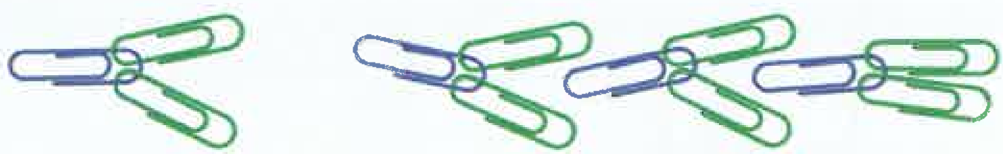
A chemical reaction is represented below. The compounds to the left of the arrow represent substances that react and undergo a change. The compounds to the right of the arrow are the new substances that form.

$$Na_3P + CaF_2 \longrightarrow Ca_3P_2 + NaF$$

How many atoms of each element are on the left-hand side of the equation? How many atoms of each element are on the right-hand side of the arrow?

Does this chemical equation reflect the conservation of mass? Explain.

Use paper clips to model this reaction. One paper clip of a given colour should represent one atom of a given element. Work with the paper clip models to represent a reaction that has the same number of each colour of paper clip in the reacting substances as the substances formed. How could you change the chemical equation to reflect your models?



CaF_2 $3 \times CaF_2$

chemical equation the representation of a chemical reaction using words or chemical formulas

reactant a substance that undergoes a chemical change

product a substance formed in a chemical change

A **chemical equation** is a statement that uses words or symbols to describe a chemical reaction. Figure 2.12 shows how information is represented in a chemical equation. A **reactant** is any substance that undergoes a chemical change in the reaction. A **product** is any new substance that is formed from the reaction. An arrow is used to point towards the end result, which is product formation.

A plus sign on the left side means "reacts with"

A plus sign on the right side means "and"

reactant A + reactant B ⟶ product C + product D

The arrow means "to produce" or "yields"

Figure 2.12 Reactants undergo chemical change to form products.

Using Chemical Equations

Figure 2.13 Magnesium and oxygen react to produce magnesium oxide. **Analyzing: Is there an overall release or absorption of energy in this reaction? What evidence supports this?**

Figure 2.13 shows the chemical reaction between magnesium metal and oxygen gas, which produces magnesium oxide. One way to represent this reaction is with a word equation:

$$\text{magnesium} + \text{oxygen} \longrightarrow \text{magnesium oxide}$$

A *word equation* uses words to describe what happens to reactants and products in a chemical reaction. However, the information it provides is limited.

Skeleton Equation (Unbalanced chemical equation)

A *skeleton equation* provides the chemical formulas for the reactants and products. However, it does not necessarily reflect the law of conservation of mass. The correct proportions of reactants and products may not be shown. In the example below, there are different numbers of atoms of oxygen on each side of the equation.

$$Mg + O_2 \longrightarrow MgO$$

Balanced Chemical Equation

According to the law of conservation of mass, atoms are never destroyed or created in a chemical reaction—they are just rearranged. So, in a *balanced chemical equation*, the same number of atoms of each element must appear on both sides of the arrow. This is achieved using **coefficients**.

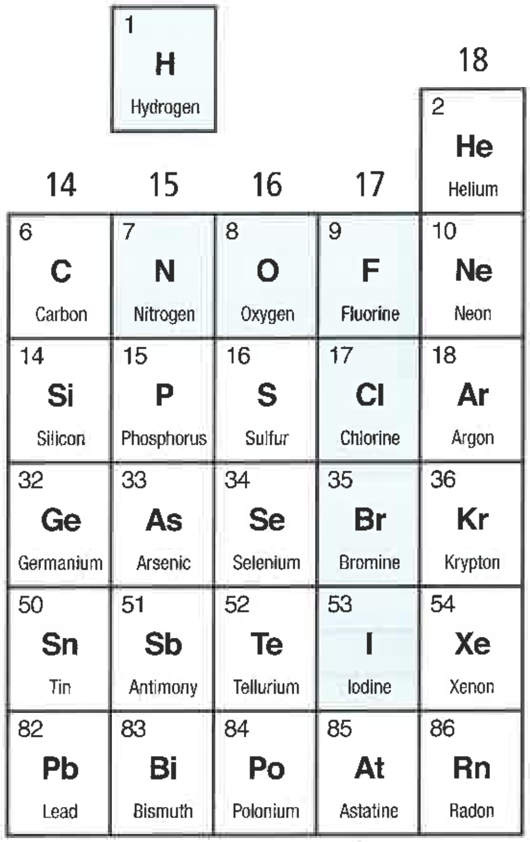
Balanced chemical equations are always written using the smallest whole number ratio of coefficients. The example below tells you that two atoms of magnesium combine with one molecule of oxygen to produce two formula units of magnesium oxide. A chemical equation may also provide information about the physical states of the reactants and products.

coefficient number placed in front of a chemical formula in a balanced chemical equation to show the ratios of substances in a reaction

A substance can be a gas (g), liquid (ℓ), or solid (s). Substances that are dissolved in water are aqueous solutions (aq).

$$2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$$

The number placed in front of a chemical formula is called a coefficient. The coefficient applies to the whole formula that it is placed in front of. Coefficients not shown are assumed to be 1.



Diatomic and Polyatomic Elements in Chemical Equations

Notice in the chemical equation on the previous page that oxygen is represented as $O_2(g)$. Recall that oxygen naturally exists as a diatomic ("two-atom") element. Other diatomic elements are hydrogen, $H_2(g)$, nitrogen, $N_2(g)$, fluorine, $F_2(g)$, chlorine, $Cl_2(g)$, bromine, $Br_2(\ell)$, and iodine, $I_2(s)$. Sulfur and phosphorus exist as the polyatomic elements $S_8(s)$ and $P_4(s)$.

A common way to remember the diatomic elements is to "visualize" them on the periodic table forming the number "7," with the exception of hydrogen (Figure 2.14).

Figure 2.14 Except for hydrogen, diatomic elements are positioned in the periodic table in the shape of a "7." **Innovating: Develop an abbreviation or other memory aid to help you remember the diatomic and polyatomic elements.**

Coefficients versus Subscripts

It is important to be clear about how subscripts in chemical formulas differ from coefficients in chemical equations. As shown in Figure 2.15, the subscripts in a chemical formula indicate how many atoms of each element are present in a molecule or formula unit. The coefficient indicates how many molecules or formula units are present.

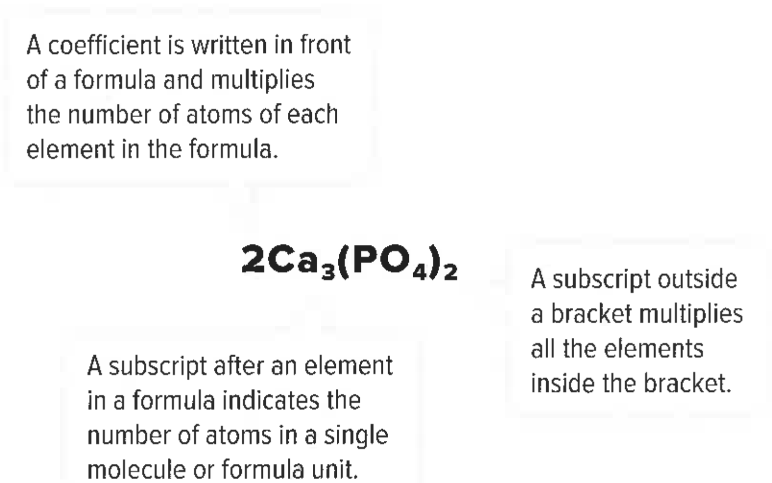


Figure 2.15 Coefficients indicate the number of molecules or formula units. **Analyzing: How many atoms of each element are represented?**

Balancing Chemical Equations

Balancing chemical equations involves applying the law of conservation of mass. The number of atoms of each element on the reactant side of the equation must equal the number of atoms of the same elements on the product side of the equation. Remember that equations are balanced using coefficients, never by changing the subscripts in chemical formulas. Changing a subscript in a chemical formula changes the identity of the compound.

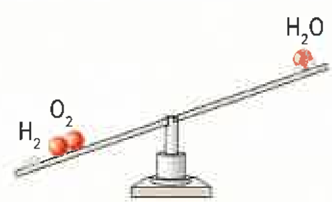
How to Balance a Chemical Equation

1. $H_2(g) + O_2(g) \longrightarrow H_2O(\ell)$

In the skeleton equation, there is the same number of hydrogen atoms on both sides of the equation. There are more oxygen atoms in the reactants, however, than in the product.

Checking the Atom Balance

Element	Reactant	Product	Equal?
H	2	2	yes
O	2	1	no

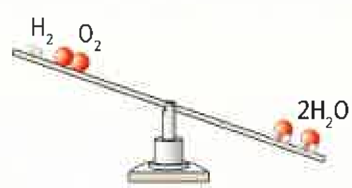


2. $H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$

Balance equations by adjusting coefficients. Placing the coefficient 2 in front of $H_2O(\ell)$ balances the oxygen atoms on each side of the equation. But now there are 4 hydrogen atoms on the product side and only 2 on the reactant side.

Checking the Atom Balance

Element	Reactant	Product	Equal?
H	2	4	no
O	2	2	yes

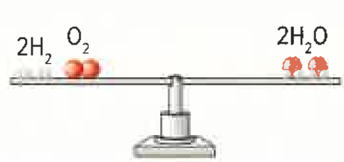


3. $2H_2(g) + O_2(g) \longrightarrow 2H_2O(\ell)$

Placing the coefficient 2 in front of $H_2(g)$ brings the total number of hydrogen atoms to 4 on each side of the equation. The equation is now balanced. Once you think the chemical equation is balanced, do a final check by counting the atoms of each element one more time.

Checking the Atom Balance

Element	Reactant	Product	Equal?
H	4	4	yes
O	2	2	yes



Tips for Balancing Chemical Equations

When balancing a chemical equation, it is important to remember that each equation is different and the identical approach does not work for every equation. However, there are some general guidelines you can follow.

- Begin by checking that all chemical formulas are correct so that you do not waste time trying to balance an equation that is not possible.
- Balance compounds first and elements last.
- When you have placed a coefficient for a compound, balance the rest of the atoms in that compound before moving on to the next substance.
- Balance atoms that appear only once on the reactant side and product side first. Elements such as hydrogen and oxygen often appear in more than one reactant or more than one product, so it is easier to balance them after the other elements are balanced.
- If a polyatomic ion appears in both a reactant and a product, treat it as a single unit.
- Once you think the chemical equation is balanced, do a final check by counting the atoms of each element on both sides of the equation.

Sample Problem 1:

Writing a Balanced Chemical Equation

In the industrial production of gaseous ammonia, gaseous nitrogen and gaseous hydrogen are the reactants. Write the balanced chemical equation for this reaction, including the states of reactants and products.

Solution

1. Begin by writing a word equation.

   nitrogen + hydrogen $\rightarrow$ ammonia

2. Write a skeleton equation. Remember that nitrogen and hydrogen are diatomic elements. Include the states.

   $N_2(g) + H_2(g) \rightarrow NH_3(g)$

3. Use coefficients to balance the equation. First consider the compound in the equation. You need to have 2 nitrogen atoms in the product to balance the nitrogen in the reactants. Therefore, place a coefficient of 2 in front of $NH_3(g)$.

   $N_2(g) + H_2(g) \rightarrow 2NH_3(g)$

Now the nitrogen atoms are balanced. The hydrogen atoms are not balanced, because there are 2 hydrogen atoms on the reactant side and 6 hydrogen atoms on the product side. Therefore, place a coefficient of 3 in front of $H_2(g)$.

   $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

4. Do a final check to make sure there are the same number of atoms of each element on both sides of the equation. There are 2 nitrogens and 6 hydrogens on both sides.

Sample Problem 2:

Writing a Balanced Chemical Equation Containing a Polyatomic Ion

Balance the following skeleton equation.

$CaCl_2(aq) + AgNO_3(aq) \longrightarrow AgCl(s) + Ca(NO_3)_2(aq)$

Solution

1. Write out the equation. Make sure that you have copied each chemical formula correctly.
2. Use coefficients to balance the equation. When a polyatomic ion appears in both a reactant and a product, treat it as a single unit. There is one NO_3^- in the reactants and two NO_3^- in the products. Since you need to have two NO_3^- in the reactants, place a coefficient of 2 in front of $AgNO_3(aq)$.

   $CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow AgCl(s) + Ca(NO_3)_2(aq)$
3. There are now two silver ions in the reactants. You know you need to have two silver ions in the products to balance these in the equation. Therefore, place a coefficient of 2 in front of $AgCl(s)$.

   $CaCl_2(aq) + 2AgNO_3(aq) \longrightarrow 2AgCl(s) + Ca(NO_3)_2(aq)$

   Notice that adding the coefficient has also balanced the number of chloride ions. The number of calcium ions also remains balanced.
4. As a final check, count the number of each type of atom on the left side of the equation and on the right side of the equation. Make sure they are the same.

Ion	Reactant	Product
Ca^{2+}	1	1
Ag^+	2	2
Cl^-	2	2
NO_3^-	2	2

Practice Problems

Balance each of the following skeleton equations.

1. $Li(s) + Br_2(g) \longrightarrow LiBr(s)$
2. $Al(s) + CuO(s) \longrightarrow Al_2O_3(s) + Cu(s)$
3. $Pb(NO_3)_2(aq) + K_3PO_4(aq) \longrightarrow KNO_3(aq) + Pb_3(PO_4)_2(s)$

For each of the following reactions, write a word equation, a skeleton equation, and a balanced chemical equation. Include the states of matter.

4. Nitrogen monoxide gas reacts with oxygen gas to form nitrogen dioxide gas.
5. Solid copper reacts with aqueous silver nitrate to form solid silver and aqueous copper(II) nitrate.
6. Potassium sulfate and silver nitrate, both dissolved in water, react to form solid silver sulfate and dissolved potassium nitrate.

AT ISSUE Can traditional methods be used to tan leather sustainably?

An essential resource for First Peoples has always been animal hides to make items such as clothing and footwear. Processing skins of animals such as caribou, moose, deer and bison requires many skills and a depth of scientific knowledge. The skins must have some type of chemicals applied to prevent decay and ensure they stay flexible and waterproof. In the method traditionally used by most Indigenous people of North America, the chemicals come from brains.

Brain-tanning is labour-intensive. It involves scraping, washing, and stretching the skin before the chemical steps begin. Usually people use the brain of the animal whose skin is being processed. The brain is mashed and cooked in water to make an emulsion rich in fats and oils. The oils help change the chemical properties of the skin, lubricating the fibres and replacing water. The final step is smoking, which seals the fibres by depositing a coating of tar-like substances on them.

What's the Issue?

Treating a raw hide involves a chemical process. Sometimes tannin-containing plants are used (hence the word tanning). First Peoples hold diverse knowledge, such as understanding how to process various types of skins, and the best type of wood to use for smoking the hides. Brain tanning is a sustainable process; it is entirely natural and helps to ensure the entire animals is used. However, modern industrial tanning involves toxic chemicals such as chromium salts.

Dig Deeper

Collaborate with your classmates to explore one or more of these questions—or generate your own questions to explore.

1. What leather products do you use in your daily life? How important is leather for you and your family?
2. Investigate First Peoples tanning in greater depth, and compare it with industrial methods. What are the pros and cons of each?
3. Do you think it would be possible to use sustainable methods to tan leather on a commercial scale? Why or why not?

Check Your Understanding of Topic 2.2

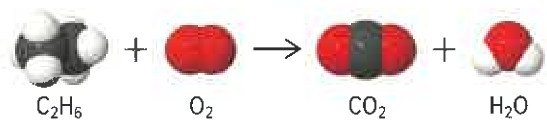
QP Questioning and Predicting PC Planning and Conducting PA Processing and Analyzing E Evaluating AI Applying and Innovating C Communicating

Understanding Key Ideas

1. What is the difference between a coefficient and a subscript of a chemical formula? PA
2. Give an example of an anion and an example of a cation. Describe how each forms. When an ionic compound forms, is it possible for a cation to form but not an anion? Justify your answer. C
3. Using a graphic organizer, such as a T-chart, compare and contrast the bonds in covalent compounds and ionic compounds. PA C
4. Iron metal reacts with oxygen gas to form solid iron(III) oxide. Write a word equation, a skeleton equation, and a balanced chemical equation for this reaction. PA E C
5. Write balanced chemical equations for each of the following. You do not need to include states for parts a) and b). PA E C
   a) potassium + iodine $\longrightarrow$ potassium iodide
   b) lead(II) nitrate + sodium chloride $\longrightarrow$ lead(II) chloride + sodium nitrate
   c) $H_2O_2(aq) \longrightarrow H_2O(\ell) + O_2(g)$
   d) $MgO(s) \longrightarrow Mg(s) + O_2(g)$
   e) $Fe(s) + H_2SO_4(aq) \longrightarrow H_2(g) + Fe_2(SO_4)_3(aq)$

Connecting Ideas

6. Explain why energy is required to break chemical bonds. Why do some bonds require more energy to break than others? PA E
7. Choose a Group 2 metal element and a halogen element that could combine to form a compound. QP PA
   a) Provide the name and chemical formula for the compound that is predicted to form.
   b) Explain why this compound would form. As part of your answer, use Bohr diagrams or Lewis diagrams to show how bond formation occurs.
8. a) Consider the definition of the term matter. The law of conservation of mass is sometimes referred to as the law of conservation of matter. Do you think this is an appropriate alternative? Justify your opinion. QP E
   b) Using the image below, describe how a balanced chemical equation represents the law of conservation of mass. Redraw the image so it represents a balanced chemical equation. C



   c) Using a table format, list the bonds that are broken and formed during the reaction. Also include whether energy is absorbed or released in each process. C

Making New Connections

9. Identify the open and closed systems that are represented below. Explain why each represents that type of system. Then give as many examples of each type of system as you can, with a minimum of five examples each. Describe what each example is used for and why it is necessary for it to be that type of system. E AI

INVESTIGATION

2-C

Skills and Strategies

- Processing and Analyzing
- Evaluating
- Communicating

Safety

- Wear safety eyewear and lab coat or apron throughout this investigation.
- Wear gloves throughout this investigation.
- Rinse any spills with plenty of water, and report them to your teacher immediately.
- Dispose of materials as directed by your teacher.

STRUCTURED INQUIRY

What You Need

Part 1:

- 25 mL graduated cylinder
- dilute sodium hydroxide solution, 0.1 mol/L NaOH(aq)
- 250 mL Erlenmeyer flask
- dilute iron(III) nitrate solution, 0.1 mol/L $Fe(NO_3)_3$(aq)
- small test tube, 8 mm × 100 mm
- rubber stopper (to fit the Erlenmeyer flask)
- electronic balance (minimum readability 0.01 g)

Part 2:

- 100 mL water
- 250 mL beaker
- electronic balance
- Alka-Seltzer™ tablet
- timer or stopwatch

The Law of Conservation of Mass

According to the law of conservation of mass, matter cannot be created or destroyed. This means that in a chemical reaction, the number of atoms of each element are the same before and after the reaction. Using open and closed systems, you will investigate the law of conservation of mass by analyzing the masses of substances in a chemical reaction.

Question

Does the total mass of substances change in a chemical reaction?

Procedure

Part 1:

1. Read Procedure steps 2 to 7. Design a table to record your results.
2. Use a graduated cylinder to measure 20 mL of dilute sodium hydroxide solution, NaOH(aq). Pour the solution into the Erlenmeyer flask.
3. Add about 5 mL of the iron(III) nitrate solution, $Fe(NO_3)_3$(aq), into the small test tube. This should be enough to fill the small test tube about half full.
4. Tilt the Erlenmeyer flask carefully and let the small test tube slide down inside, as shown in the photograph. Do not let the solutions mix. Seal the flask with the stopper.

5. Measure the mass of the flask and its contents. Record your measurement. Also record your observations about the appearance of the contents of the flask.
6. Tip the flask so that the solutions mix. Observe what happens and record your observations.
7. When the reaction is complete, measure the mass of the flask and its contents. Record your measurement.
8. Clean up your work area and dispose of any materials according to your teacher's instructions.

Part 2:

1. Read Procedure steps 2 to 4. Design a table to record your results.
2. Pour 100 mL of water into a 250 mL beaker.
3. Determine the masses of the beaker with water and an Alka Seltzer™ tablet. Place the tablet next to the beaker on the balance. Do not add the tablet into the water. Record the mass and any other observations.
4. Leaving the beaker of water on the balance, place the tablet in the water. Observe what happens and record the mass every 30 seconds, using a stopwatch or timer to monitor the time. Continue until most of the bubbling has stopped (about 10 minutes). Record your observations of the final solution.
5. Clean up your work area, and dispose of any materials according to your teacher's instructions.

Process and Analyze

1. What did you observe that tells you a chemical reaction took place in Part 1? in Part 2?
2. Graph the data you collected in Part 2. What labels will you use for the x-axis and y-axis?

Conclude and Communicate

3. Identify the closed system and the open system in this investigation. Provide an explanation for your answer.
4. For Part 1, how did the initial mass of the chemicals, flask, test tube, and stopper compare with their mass after the reaction? Do you think you would see similar results if you carried out an investigation like this with different reacting chemicals? Explain your answer.
5. What did you observe during the reaction in Part 2? Provide an explanation for this. What do you think the results would have been if you had sealed the opening of the beaker? Explain why.