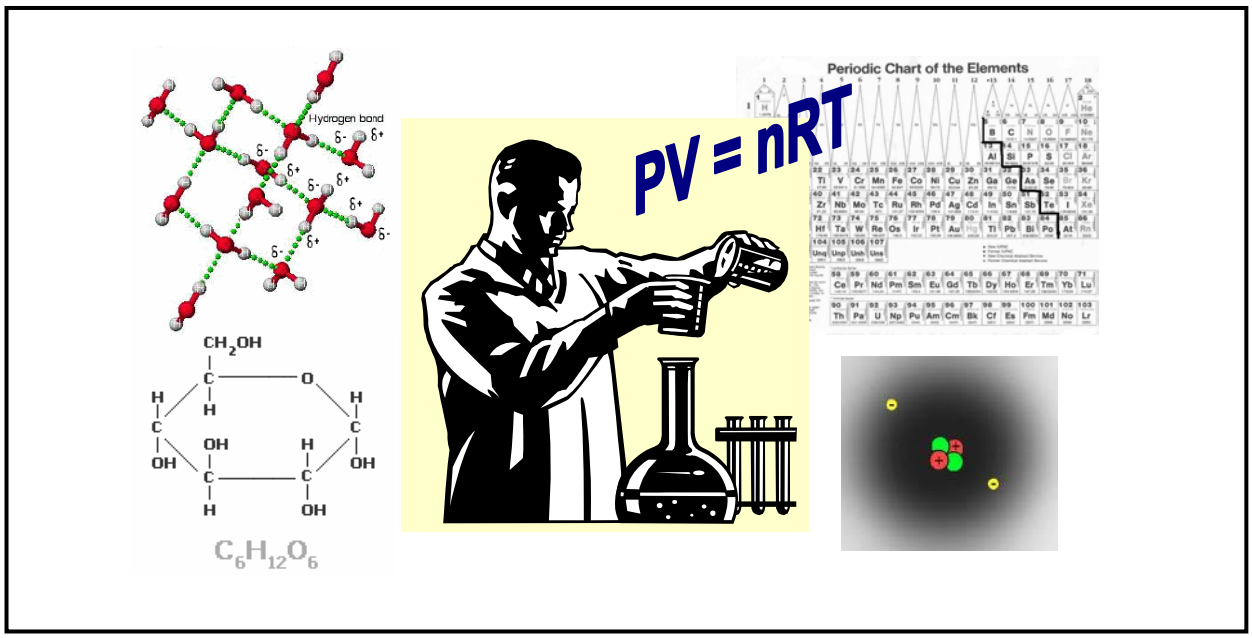
Project EASE

(Effective Alternative Secondary Education)

CHEMISTRY



MODULE 13

Chemical Reactions

BUREAU OF SECONDARY EDUCATION
Department of Education
DepEd Complex, Meralco Avenue
Pasig City

Module 13
Chemical Reactions

What this module is about

Chemical reactions take place in our surroundings as fast as we can take air for breathing. A very pleasant reaction takes place in our homes while preparing grilled fish or pork for the evening meal. The glowing charcoal that cooks the fish or pork consists almost entirely of the element carbon. It burns slowly with oxygen of the evening air. When carbon and oxygen combine together, what compound is produced?

While taking your shower, have you ever wondered how the soap is made? Have you ever thought that regardless of color, shape and brand its main function is to take off dirt from the body?

As the cars and buses move, have you thought about how these machines work? Did you know that chemical reactions take place inside the car batteries?

These are just examples of chemical changes that we find in our environment. These changes have been found to comply with several basic laws of nature. This module introduces you to these laws.

In addition to that, we will learn how to write sample chemical reactions and translate them into chemical equations. This module will lead you to the beauty of the chemical language to the extent that you will be able to write it, read it and interpret its meaning.

- **Lesson 1 – Law of Conservation of Mass**
- **Lesson 2 – Law of Definite Proportions**
- **Lesson 3 – Law of Multiple Proportions**
- **Lesson 4 – Writing Chemical Reactions and Balancing Chemical Equations**

What you are expected to learn

After going through this module, you should be able to:

1. identify reactants and products.
2. evaluate chemical equations that conform with the law of conservation of mass.
3. describe the characteristics of a chemical reaction.

4. solve problems involving the law of definite proportions.
5. evaluate compounds that conform with the law of multiple proportions.
6. write chemical reactions.
7. balance chemical equations.
8. explain the implied information derived from a balanced equation.

How to learn from this module

Here are some helpful reminders before getting started:

1. Review lessons in writing chemical symbols and formula
2. Take the pretest before proceeding to the lessons.
3. Perform the activities and read the discussions provided for in the lessons.
4. Answer the Self-Test. Compare your answers with the keys to correction.
5. Consult a dictionary if you are not sure of the meaning of some words used in this module.
6. Answer the posttest so that you will know how much you have learned from the lessons.
7. Keep an open mind to the new concepts you will be learning in this module.

Happy reading!

What to do before (Pretest)

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Which of the following is true of a chemical reaction?
   a. Only physical changes occur.
   b. New substances must form.
   c. Only changes of state occur.
   d. Chemical properties remain the same.

2. A substance that enters into a chemical reaction is called a
   a. mole
   b. product
   c. coefficient
   d. reactant

3. A substance that is formed by a chemical reaction is called a
   a. mole
   b. product
   c. coefficient
   d. reactant

4. When oxygen is available, sulfur dioxide is produced from the burning of sulfur. Which of the following word equations best represents this reaction?
   a. sulfur + oxygen → sulfur dioxide
   b. sulfur dioxide + oxygen → sulfur
   c. sulfur dioxide → sulfur + oxygen
   d. sulfur → sulfur dioxide + oxygen

5. In a chemical equation, the symbol that takes the place of the words '*reacts with'* is a (n)
   a. equal sign
   b. coefficient
   c. plus sign
   d. arrow

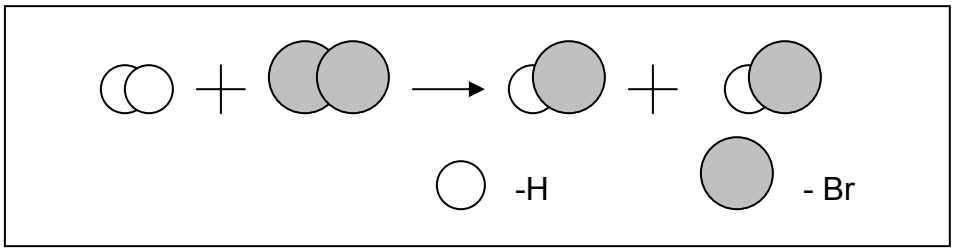
6. Which of the following is **TRUE** of a balanced equation?
   a. The total number of atoms remains the same.
   b. The kinds of atoms remain the same.
   c. The total number of molecules remains the same.
   d. The number of atoms of each element remains the same.

7. In a chemical equation, the number of molecules of a given substance is indicated by a
   a. subscript
   b. coefficient
   c. superscript
   d. reaction number

8. The symbol(s) written after a formula in a chemical equation stands for
   a. soluble
   b. solution
   c. solid
   d. synthesis

9. What number should be written in front of Na to balance the equation
   $Na + MgCl_2 \rightarrow NaCl + Mg$?
   a. 1
   b. 2
   c. 3
   d. 4

Use the diagram to answer questions 10 – 14.



10. What word equation describes the reaction in the figure above?
    a. Hydrogen plus bromine are formed from hydrogen bromide.
    b. Hydrogen plus bromine yields hydrogen plus bromine.
    c. Hydrogen plus hydrogen bromide yields bromine.
    d. Hydrogen plus bromine yields hydrogen bromide.

11. What formula equation describes the reaction?
    a. $H_2 + Br_2 \rightarrow H_2Br_2$
    b. $2\,H + 2\,Br \rightarrow 2HBr$
    c. $H_2 + Br_2 \rightarrow HBr$
    d. $2H + 2\,Br \rightarrow H_2Br_2$

12. What is the balanced formula equation for the reaction shown in the figure?
    a. $H_2 + Br_2 \rightarrow 2HBr$
    b. $2H + 2Br \rightarrow 2HBr$
    c. $H_2 + Br_2 \rightarrow H_2Br_2$
    d. $H_2 + Br_2 \rightarrow HBr + HBr$

13. Identify the product(s) in the figure
    a. hydrogen only
    b. both hydrogen and bromine
    c. hydrogen bromide only
    d. both bromine and hydrogen bromide

14. Identify the reactant(s) in the figure
    a. hydrogen only
    b. both hydrogen and bromine
    c. hydrogen bromide only
    d. both bromine and hydrogen bromide

15. What scientific principle is reflected in a balanced equation?
    a. The law of conservation of mass
    b. The law of conservation of atoms
    c. The law of multiple proportions
    d. The law of definite proportions

16. Why can't you change the formula in order to balance a reaction?
    a. The number of atoms in the left should be equal to the atoms on the right of the arrow.
    b. The elements that combine have definite composition and fixed proportion of elements by mass.
    c. The elements have definite mass ratios.
    d. The molecule is indestructible.

17. Which equation conforms with the Law of Conservation of Mass?
    a. $2Al_{(l)} + BaO_{(s)} \rightarrow Al_2O_{3(s)} + 3Ba_{(l)}$
    b. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$
    c. $Cl_{2(g)} + KBr_{(aq)} \rightarrow 2KCl_{(aq)} + Br_{2(l)}$
    d. $2Na_{(s)} + H_2O_{(l)} \rightarrow 2\,NaOH_{(s)} + H_{2(g)}$

18. Which statement conforms with the law of definite proportions?
    a. The mass of hydrogen is twice that of oxygen in a water molecule.
    b. When mixtures of gaseous H_2 and gaseous Cl_2 react, a product forms that has the same properties regardless of the relative amounts of H_2 and Cl_2 used.
    c. Several compounds have the same composition as long as they have the same ratios.
    d. Compounds have similar proportions as long as they are solid.

19. Which set of compounds illustrates the law of multiple proportions?
    a. CH_4, CO, CCl_4
    b. N_2O, NO, NO_2
    c. NaCl, NaBr, NaI
    d. HF, F_2S, FCl_3

20. Which statement is true?
    a. When two elements form a series, they have the same composition.
    b. When two elements combine, there are always two compounds formed.
    c. When two elements combine, the first element is twice as much as the second.

d. When two elements form a series of compounds, the ratio of the second element that combines with 1g of the first element can be reduced into small whole numbers.

Key to answers on page 22.

If your score is

18-20 Very good. You have the option to skip the module but you are still encouraged to go through it.

14-17 Good! Go over the items that you find difficult and then you may proceed to the lessons in this module that you don't understand

0-10 Don't worry about your score. Read this module. This module is prepared in order for you to understand the chemical reactions.

So, what are you waiting for?

Your journey begins here……..

Lesson 1. The Law of Conservation of Mass

In the late eighteenth century, Antoine Lavoisier, a French chemist, recognized the importance of accurate measurements. He extensively studied and explained the nature of combustion. He found out that combustion involved reaction with oxygen. His experiments, in which he carefully weighed the reactants and products of various reactions, suggested that ***mass is neither created nor destroyed***. Lavoisier's discovery of this **law of conservation of mass** was the basis for the development in chemistry in the nineteenth century.

A chemical change involves reorganization of the atoms in one or more substances. The law of conservation of mass requires that there must be exactly as many atoms among the combined products of a chemical reaction as in its combined reactants. To understand this better, let us define words that will be used in this lesson. **Reactants** are the starting material in a chemical reaction. **Products** are the substance formed as a result of a chemical reaction. In a chemical equation, reactants are found on the left side and the products are on the right side. A chemical reaction can therefore be summarized as

Reactants → Products

For example, when the methane (CH_4) in natural gas combines with oxygen (O_2) in the air and burns, carbon dioxide (CO_2) and water (H_2O) are formed.

The balanced chemical equation for this reaction is:

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

The reactants in this reaction are methane and oxygen gas. The products are carbon dioxide and water.

A balanced equation conforms to the law of conservation of mass. Let us check if the number of atoms of each kind on the left side of the reaction is equal to the number of atoms of each kind on the right side of the equation.

There is 1 atom of carbon on the left side and 1 atom of carbon on the right side.

There are 4 atoms of hydrogen on the left side. On the right side, there are 2 atoms of hydrogen that is multiplied by the coefficient 2 found on the left side of H_2O.

On the left side of the equation, there are 2 atoms of oxygen multiplied by the coefficient 2 found on the left side of O_2. On the right side, there are two atoms of oxygen in CO_2 and 1 atom of oxygen in H_2O multiplied by the coefficient 2 found on the left side of H_2O.

To get a clearer view of the number of atoms of each kind, look at the table below

Kind of Atom	No. on Left side	No. on Right side
C	1	1
H	4	2 x 2 = 4
O	2 x 2 = 4	2 + 1(2) = 4

Thus, the balanced equation above conforms to the law of conservation of mass.

Let us have another example.

When aluminum and barium oxide are heated together, a vigorous reaction begins, and elemental barium and aluminum oxide, Al_2O_3, are formed. The equation is

$$2Al_{(l)} + 3BaO_{(s)} \rightarrow Al_2O_{3(s)} + 3Ba_{(l)}$$

a. Identify the reactants and products.
b. Check the equation if it conforms with the Law of Conservation of Mass.

Answer:

a. The reactants are Al and BaO. The products are Al_2O_3 and Ba.

b.

Kind of Atom	No. on Left side	No. on Right side
Al	1 x 2 = 2	2
Ba	1 x 3 = 3	1 x 3 = 3
O	1 x 3 = 3	3

It conforms with the Law of Conservation of Mass.

Your Turn

Identify the reactants and products of the reaction. Check the equation if it conforms with the Law of Conservation of Mass.

1. $Cl_{2(g)} + 2\ KBr_{(aq)} \rightarrow 2KCl_{(aq)} + Br_{2(l)}$
2. $2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(s)} + H_{2(g)}$
3. $K_2CrO_{4(aq)} + 2AgNO_{3(aq)} \rightarrow Ag_2CrO_{4(s)} + KNO_{3(aq)}$

Solution:

a. The reactants are compounds found on the left, the products are the compounds on the right

b. No. 3 does not conform with the law of conservation of mass. The equation is not balanced.

Another application of the Law of Conservation of Mass in chemical reactions is to predict the mass of the products when the mass of the reactants are known. If the Law of Conservation of Mass holds, the total mass of reactants must equal the total mass of the products. Therefore,

Total mass reacted = Total mass produced

Going back to our first example, if 46.0 g of methane reacts with 96.0 g of oxygen to produce 54.0 g water, how much carbon dioxide is produced?

$$CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$$

46.0 g + 96.0 g = Carbon dioxide + 54.0 g
142.0 g - 54.0 g = 88.0 g carbon dioxide

Your Turn

In the reaction shown below,

$$2Al_{(l)} + 3BaO_{(s)} \rightarrow Al_2O_{3(s)} + 3Ba$$

65.0 g of Aluminum reacted with 35.0 g of Barium oxide to produce aluminum oxide and barium. If 84.0 g of aluminum oxide is produced, how much barium is produced?

Solution: 16 g Ba

What you will do

Self-Test 1.1

Answer the following questions.

1. You have a chemical in a sealed glass container filled with air. The system has a mass of 250.0 g. The chemical is ignited by means of a magnifying glass focusing sunlight on the reactant. After the chemical is completely burned, what is the mass of the system?

2. Check the following reactions if it conforms with the Law of Conservation of Mass.
   a. $N_2O_{5(g)} \rightarrow N_2O_{4(g)} + O_{2(g)}$
   b. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$
   c. $H_3PO_{4(aq)} + 3NH_{3(aq)} \rightarrow (NH_4)_3PO_{4(aq)}$

3. Identify the reactants and products in no. 2.

Key to answers on page 22.

Lesson 2. Law of Definite Proportions

After Lavoisier, another French scientist studied the composition of various chemical compounds. Joseph Proust showed that ***a given compound always contains exactly the same proportion of elements by mass.*** The principle of the constant composition of compounds, originally called Proust's Law, is also known as the **Law of Definite Proportions.** Another way of stating the law is that different samples of the same compound always contain its constituent elements in the same proportions by mass**.** Elements combine in fixed proportion when they form a compound.

Example:

A sample of chloroform, $CHCl_3$, is found to contain 12.0 g of carbon, 106.4 g chlorine, and 1.01 g hydrogen. If a second sample is found to contain 30.0 g of carbon, how many grams of chlorine and of hydrogen does it contain?

Strategy:

Using the law of definite proportions, ***the ratios of the weights of the elements in chloroform are constant.*** Therefore, we have to find the ratio of carbon and the factor must hold true for chlorine and hydrogen.

Solution:

a. Finding the ratio for carbon: 30.0 g/12.0 g = 2.5. The 2.5 means that carbon is increased by a factor of 2.5. Thus, it will hold true for Cl and H.
b. Finding the mass for chlorine in sample 2: 106.4 (2.5) = 266 g Cl
c. Finding the mass for hydrogen in sample 2: 1.01 (2.5) = 2.53 g H

This law can be applied when doing chemical reactions. When there is 30.0 g of carbon, 300 g of Chlorine, and 3.00 g of Hydrogen to form chloroform, only 266 g of chlorine and 2.53 g of hydrogen are used up in the reaction.

What you will do

Activity 2.1

Solve the following problems.

1. A compound is composed of 23.0 g sodium and 35.0 g chlorine. If 105.0 g of chlorine is available for reaction, what mass of sodium is needed to complete the salt reaction?

2. The ratio of hydrogen to chlorine is 1:35. What mass of chlorine is needed when there are 25 g of chlorine available to produce hydrochloric acid?

3. Proust discovered that the substance copper carbonate is always 5.3 parts copper to 4 parts oxygen to 1 part carbon. When 60 g of copper is present in the compound, what are the masses of oxygen and carbon?

Key to answers on page 22.

Were you able to answer the questions in Activity 2.1? You are now ready to take the test for this lesson.

What you will do

Self-Test 2.1

Provide the needed answer for the following questions:

1. Which statement conforms with the law of definite proportions?

    a. The mass of hydrogen is twice that of oxygen in a water molecule.
    b. When mixtures of gaseous H_2 and gaseous Cl_2 react, a product forms that has the same properties regardless of the relative amounts of H_2 and Cl_2 used.
    c. Several compounds have the same composition as long as they have the same ratios.
    d. Compounds have similar proportions as long as they are solid.

2. A reaction of 1 L of chlorine gas (Cl_2) with 3 L of fluorine gas (F_2) yields 2 L of a gaseous product. All gas volumes are at the same temperature and pressure. What is the formula of the gaseous product?

3. Sulfur and oxygen can react to form sulfur dioxide. In sample 1, there are 32.06 g of sulfur and 32.00 g of oxygen. In sample 2, there are 16.03 g of sulfur. What is the mass of oxygen in sample 2? If the sulfur in sample 1 is increased by a factor of three, what mass of oxygen is needed to complete the reaction?

Key to answers on page 22.

Lesson 3. The Law of Multiple Proportions

Proust's discovery inspired John Dalton, an English school teacher, to think about atoms. The Law of Definite Proportions explained why the same relative masses of elements were always found in a given compound. Dalton discovered another principle. He noted that carbon and oxygen form two different compounds that contain different relative amounts of carbon and oxygen as shown by the following data:

	Mass of oxygen that combines with 1 g of carbon
Compound no. 1	1.33 g
Compound no. 2	2.66 g

Dalton noted that compound 2 contained twice as much oxygen per gram of carbon as compound 1. Compound 1 might be a CO and compound 2 might be CO_2. This phenomenon can be further explained in a backyard grilling activity.

Imagine you are preparing grilled fish for supper. The fish is sizzling over hot charcoal. The glowing charcoal that cooks the fish consists mostly of the element carbon. It burns slowly with oxygen of the evening air. In the overall reaction, one atom of carbon combines with a diatomic molecule of oxygen to produce one molecule of carbon dioxide. When plenty of oxygen is available, the following reaction occurs in the grill.

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$$

When charcoal burns in an enclosed space, such as a closed room where there isn't enough oxygen to convert all the carbon to carbon dioxide, lethal carbon monoxide, CO, forms. When there is insufficient oxygen, the reaction becomes

$$2C_{(s)} + O_{2(g)} \rightarrow 2CO_{(g)}$$

This principle, which was found by Dalton to apply to compounds of other elements as well, became known as the **law of multiple proportions**. *When two elements form a series of compounds, the ratios of the masses of the second element that combine with 1 gram of the first element can always be reduced to small whole numbers.*

These ideas are illustrated by the compounds of nitrogen and oxygen, as shown by the following data:

	Mass of nitrogen that combines with 1 g of oxygen
Compound 1	1.750 g
Compound 2	0.8750 g
Compound 3	0.4375 g

which yields the following ratios:

$$\frac{1}{2} = \frac{1.750}{0.8750} = \frac{2}{1}$$

$$\frac{1}{3} = \frac{1.750}{0.4375} = \frac{4}{1}$$

$$\frac{2}{3} = \frac{0.8750}{0.4375} = \frac{2}{1}$$

The significance of these data is that compound 1 contains twice as much nitrogen per gram of oxygen as does compound 2 and that compound 1 contains four times as much as in compound 3. Compound 2 contains twice as much as compound 3. In terms of the number of atoms combining, these are some of the possible sets of formulas:

	First Series	Second Series	Third Series
Compound 1	N_2O	NO	N_4O_2
Compound 2	NO	NO_2	N_2O_2
Compound 3	NO_2	NO_4	N_2O_4

Your Turn

1. Sulfur and oxygen can react to form both sulfur dioxide and sulfur trioxide. In sulfur dioxide, there are 32.06 g of sulfur and 32.00 g of oxygen. In sulfur trioxide, 32.06 g of sulfur are combined with 48.00 g of oxygen.
    a. What is the ratio of the weights of oxygen that combine with 32.06 g of sulfur?
    b. How do these data illustrate the law of multiple proportions?

2. Several compounds containing only sulfur (S) and fluorine (F) are known. Two of them have the following compositions:
    i. 1.188 g of F for every 1.000 g of S
    ii. 2.375 g of F for every 1.000 g of S

    a. What is the ratio of the two Fluorine samples?
    b. What are the possible formulas for the two compounds?

Solution:

1. *a. The ratio is 1.5 to 1 or 3 to 2.*
   b. The ratios are two whole numbers.
2. *a. The ratio is 1 is to 2.*
   b. F_2S, F_2S_2

What you will do

Self-Test 3.1

Answer the following questions.

1. Which set of compounds illustrates the law of multiple proportions?
    a. CH_4, CO, CCl_4
    b. N_2O, NO, NO_2
    c. NaCl, NaBr, NaI
    d. HF, F_2S, FCl_3

2. Which statement is true?
    a. When two elements form a series, they have the same composition.
    b. When two elements combine, there are always two compounds formed.
    c. When two elements combine, the first element is twice as much as the second.
    d. When two elements form a series of compounds, the ratio of the second element that combines with 1 g of the first element can be reduced into small whole numbers.

3. Nitrogen and oxygen react to form dinitrogen oxide and nitrogen oxide. In dinitrogen oxide, there are 28.0 g of nitrogen and 16.0 g of oxygen. In nitrogen oxide, 14.0 g of nitrogen combine with 16.0 g oxygen.
    a. What is the ratio of the weights of nitrogen that combine with 16.0 g oxygen?
    b. How do these data illustrate the law of multiple proportions?

Key to answers on page 22.

Lesson 4. Writing Chemical Reactions and Balancing Chemical Equations

The three fundamental chemical laws are the basis for writing chemical reactions. The conversion of substances to other substances during a chemical reaction is usually represented by a chemical equation. The chemical equation is very important because it provides two types of information: the nature of reactants and products, and the relative number of each. This lesson is broken in two parts to make your learning easier.

A. Writing Chemical Reactions

Writing chemical reactions are important for chemists. It is an important language that translates the reactions into easy, readable and understandable sentence, which we call the chemical equation. Word reactions are translated into symbols for easy reading. By looking at the chemical equations, the reader can easily interpret what transpired in the reaction.

For example: The reaction of hydrogen and oxygen to give water is represented as follows:

$$2H_2 + O_2 \rightarrow 2H_2O$$

There are conventions and simple rules to follow in writing chemical equations. They are as follows:

1. As mentioned in Lesson 1, the starting material or substances called reactants

are written on the left side and the resulting substances called products are written on the right side.

2. An arrow (→) is used to represent the conversion of the reactants to products. This may literally mean "to yield" or "to form". The plus sign (+) means "to react with" or "to combine with".

3. It is recommended that the states of the substances be indicated by placing the following symbols after the formula of the substance.

Symbol	Meaning
(s)	solid
(l)	liquid
(g)	gas
(aq)	aqueous
(cr)	Crystalline

For example, the following equation is more descriptive of the reaction given earlier:

$$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$$

The above reaction indicates that the water produced is in liquid form. Under other conditions, the water produced may be in gaseous state.

4. In a chemical reaction, the law of conservation of mass holds. A balanced equation conforms to this law. As mentioned in the previous lesson, the number of atoms of each kind on the left and right sides of the arrow must be equal.

Try this:

Write the chemical equation for this reaction:

Two molecules of acetylene gas will react with 5 molecules of oxygen gas to produce 4 molecules of carbon dioxide gas and two molecules of water vapor.

Strategy:

1. Identify the reactants and products: $C_2H_2 + O_2 \rightarrow CO_2 + H_2O$

2. Indicate the states of the substances by placing their symbols on the right side of the substances

$$C_2H_{2(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$$

3. Affix the number of molecules as coefficients at the left side of the substances

$$2C_2H_{2(g)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O_{(g)}$$

4. Check the equation if it conforms with the Law of Conservation of Mass.

Kind of atom	Left side	Right side
C	2 x 2 = 4	1 x 4 = 4
H	2 x 2 = 4	2 x 2 = 4
O	2 x 5 = 10	2(4) + 1(2) = 10

Your turn

Write the chemical equation of the following chemical reactions. Check the equation if it conforms with the Law of Conservation of Mass.

1. Aqueous aluminum hydroxide decomposes to form solid aluminum oxide and liquid water.
2. One molecule of solid magnesium nitride reacts with six molecules of liquid water to form three moles of aqueous magnesium hydroxide and two moles of aqueous ammonia.
3. Two molecules of silver nitrate react with sulfuric acid to produce silver sulfate and two molecules of nitric acid.
4. Potassium nitrate decomposes to produce potassium nitrite and oxygen gas.

Solution:

A. 1. $Al(OH)_{3(aq)} \rightarrow Al_2O_{3(s)} + H_2O_{(l)}$

2. $Mg_3N_{2(s)} + 6H_2O_{(l)} \rightarrow 3Mg(OH)_{2(aq)} + 2NH_{3(aq)}$

3. $2AgNO_3 + H_2SO_4 \rightarrow Ag_2SO_4 + 2HNO_3$

4. $KNO_3 \rightarrow KNO_2 + O_{2(g)}$

B. 1 & 4 do not conform with the Law of Conservation of Mass

B. Balancing Equations

Equations 1 & 4 in the previous exercise are examples of unbalanced equations. There is a way in which the atoms on the left and the right side of the arrow will be equal. This section will focus on the procedure of balancing equations by inspection.

In general, a balanced chemical equation is written in two steps:

1. Write the formula and state or phase of the reactants and products.

2. Balance the number of atoms of each kind by using coefficients. Write the coefficients on the left side of the substances.

Note: *The chemical formulas must not be changed. The subscripts must not be changed. Only the coefficients are to be adjusted.*

Example 1.

Write the balanced equation for the reaction of solid magnesium with oxygen in air to produce magnesium oxide.

Step 1. Write the chemical equation

$$Mg_{(s)} + O_{2(g)} \rightarrow MgO_{(s)}$$

Step 2. Balance the number of atoms

$$Mg_{(s)} + O_{2(g)} \rightarrow MgO_{(s)}$$

Upon inspection, there are 2 atoms of oxygen in the left side, and only 1 atom of oxygen on the right side. Thus, we shall focus on balancing the oxygen atom on the right side by putting a coefficient 2 at the left side of MgO.

$$Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$$

The oxygen atom is now balanced, but there is only 1 atom of Mg on the left side and two atoms on the right side. The next move is to put a coefficient 2 on the left side of Mg to balance the Mg atoms.

$$2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$$

Step 3. Check the equation if it conforms with the Law of Conservation of Mass.

Example 2. Let us take for example equation 1 of the previous exercise.

Step 1. Write the formula

$$Al(OH)_{3(aq)} \rightarrow Al_2O_{3(s)} + H_2O_{(l)}$$

Step 2. Balance the number of atoms

$$Al(OH)_{3(aq)} \rightarrow Al_2O_{3(s)} + H_2O_{(l)}$$

Upon inspection, there are 2 atoms of aluminum on the right side, and only 1 atom of aluminum on the left side. Thus, we shall focus on balancing the aluminum

atom on the left side by putting a coefficient 2 at the left side of $Al(OH)_3$.

$$2Al(OH)_{3(aq)} \rightarrow Al_2O_{3(s)} + H_2O_{(l)}$$

The aluminum atom is now balanced. On the left side of th equation, there are 6 atoms of oxygen and 6 atoms of hydrogen. On the right side, there are 4 atoms of oxygen and 2 atoms of hydrogen. It is suggested that we balance the hydrogen first. The subscript of hydrogen in water is 2. To make it 6, we need to put a coefficient 3 on the left side of water.

$$2Al(OH)_{3(aq)} \rightarrow Al_2O_{3(s)} + 3H_2O_{(l)}$$

The aluminum atom and the hydrogen atom are now balanced. Further inspection reveals that the oxygen atom is also balanced.

Step 3. Check the equation if it conforms with the Law of Conservation of Mass.

Your turn

Balance the following equations:

1. $KNO_3 \rightarrow KNO_2 + O_{2(g)}$
2. $H_{2(g)} + I_{2(g)} \rightarrow HI_{(g)}$
3. $Al_{(s)} + O_{2(g)} \rightarrow Al_2O_{3(s)}$
4. $H_3PO_{4(aq)} + NH_{3(aq)} \rightarrow (NH_4)_3PO_{4(aq)}$

Solution:

1. $2KNO_3 \rightarrow 2KNO_2 + O_{2(g)}$
2. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$
3. $4Al_{(s)} + 3O_{2(g)} \rightarrow 2Al_2O_{3(s)}$
4. $H_3PO_{4(aq)} + 3NH_{3(aq)} \rightarrow (NH_4)_3PO_{4(aq)}$

What you will do

Self-Test 4.1

A. Write the chemical equations of the following reactions:

1. Aqueous aluminum nitrate reacts with aqueous sodium hydroxide to form aqueous aluminum hydroxide and aqueous sodium nitrate.
2. Iron reacts with sulfuric acid to produce iron (III) sulfate and hydrogen gas.
3. Oxygen gas reacts with carbon sulfide to produce carbon dioxide and sulfur dioxide.

B. Balance the following chemical reactions

1. $Mg + N_2 \rightarrow Mg_3N_2$
2. $Cl_{2(g)} + KBr_{(aq)} \rightarrow KCl_{(aq)} + Br_{2(l)}$
3. $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

Key to answers on page 23.

Let's Summarize

This module is almost at its end. I hope you had a great time learning the fundamental chemical laws, writing reactions and balancing equations. To help you remember the key concepts discussed, let us go through them one more time.

A. The three fundamental chemical laws are:

1. The Law of Conservation of Mass by Lavoisier

   Mass is neither created nor destroyed. In a chemical reaction, the number of atoms of each kind on the left and right sides of the arrow must be equal.

2. The Law of Definite Proportions by Proust

   A given compound always contains exactly the same proportion of elements by mass. That is why it is prohibited to change the subscripts of the formula in balancing equations.

3. The Law of Multiple Proportions

   When two elements form a series of compounds, the ratios of the masses of the second element that combine with 1 gram of the first element can always be reduced to small whole numbers.

B. Writing chemical reactions

1. Chemists use equations to describe the changes that substances undergo. The physical state of substances in the equation is shown by writing them at the right side of the substance: ***g*** for gas, ***l*** for liquid, ***s*** for solid and ***aq*** for water solution of the substances.

2. Reactants are the starting substances in a reaction. Products are the substances resulting from a reaction. Reactants are on the left of the equation and the

products are on the right side of the equation. The arrow (→) means "to produce" or "to form". The plus sign (+) means "to combine with" or "to react with".

C. Balancing equations

1. Write the chemical equations. Be sure your formulas are correctly written.

2. Balance the number of atoms of each kind by using coefficients. Write the coefficients on the left side of the substance.

3. Check the chemical equation if it conforms with the Law of Conservation of Mass.

Posttest

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Which of the following is **NOT** an example of a chemical change?
   a. rusting iron
   b. an apple ripening
   c. cutting paper
   d. a piece of wood burning

2. In a reaction in which hydrogen reacts with oxygen to produce water, which substances are the reactants?
   a. hydrogen only
   b. oxygen only
   c. both hydrogen and oxygen
   d. water

3. In a chemical equation, the symbol that takes the place of the word '*yield*' is a(n)
   a. equal sign
   b. coefficient
   c. plus sign
   d. arrow

4. The word equation "magnesium reacts with chlorine to produce magnesium chloride" is represented by which of the following equations?
   a. $Mg \rightarrow Cl_2 + MgCl_2$
   b. $MgCl_2 \rightarrow Mg + Cl_2$
   c. $MgCl_2 + Mg \rightarrow Cl_2$
   d. $Mg + Cl_2 \rightarrow MgCl_2$

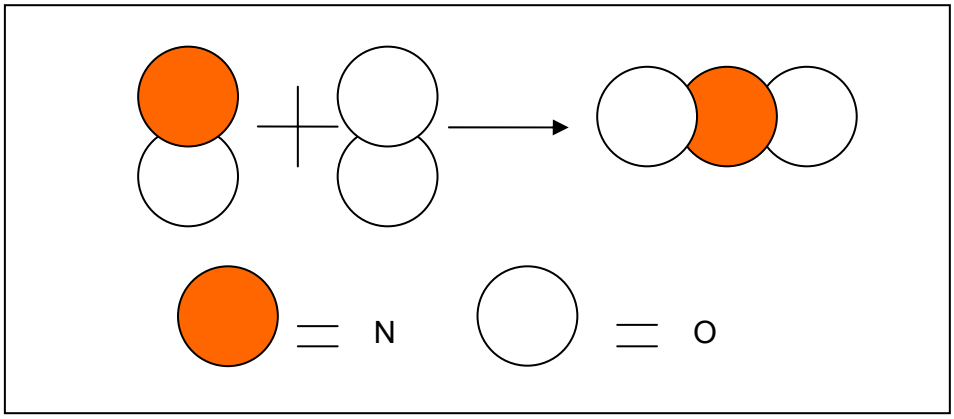
5. In a chemical reaction, what is the relationship between the total mass of the reactants and the total mass of the products?
   a. They must be equal.
   b. The mass of the products must be greater.
   c. The mass of the reactants must be greater.
   d. There is no general relationship between the two.

6. In balancing a chemical equation, which of the following are you allowed to do?
   a. change subscripts
   b. write coefficients
   c. change superscripts
   d. add new substances

7. Which of the following symbols means a substance is in water solution?
   a. (aq)
   b. (s)
   c. (w)
   d. (l)

8. What number should be written in front of O_2 to balance the equation $4Al + O_2 \rightarrow Al_2O_3$?
   a. 1
   b. 2
   c. 3
   d. 6

For questions 9-15, refer to the figure below:



9. From left to right, what are the chemical formulas for the substances represented in the figure above?
   a. NO, N_2, N_2O
   b. NO, O_2, N_2O
   c. N_2, O_2, NO_2
   d. NO, O_2, NO_2

10. What is the formula equation for the reaction in the figure?
   a. $NO + O_2 \rightarrow NO_2$
   b. $NO + O_2 \rightarrow N_2O$
   c. $N_2 + O_2 \rightarrow NO_2$
   d. $NO_2 \rightarrow NO + O_2$

11. In the figure, how many of each kind of atom is represented in the product?
   a. 1 nitrogen, 3 oxygen
   b. 1 nitrogen, 2 oxygen
   c. 2 nitrogen, 2 oxygen
   d. 2 nitrogen, 4 oxygen

12. In the figure, how many of each kind of atom is represented in the reactants?
   a. 1 nitrogen, 3 oxygen
   b. 1 nitrogen, 2 oxygen
   c. 2 nitrogen, 2 oxygen
   d. 2 nitrogen, 4 oxygen

13. In the figure, which of these statements is **TRUE**?
   a. The equation is balanced for both kinds of atoms.
   b. The equation is balanced for oxygen only.

c. The equation is balanced for nitrogen atoms only.
d. The equation is not balanced for either kind of atom.

14. Assume that the number of oxygen molecules on the left side of the equation in the figure is held at one. What can you do to balance the equation?
    a. Nothing; it is already balanced.
    b. Change the molecule on the right by adding another oxygen atom.
    c. Add one NO molecule and one NO_2 molecule to the equation.
    d. Add two NO molecules and two NO_2 molecules to the equation.

15. What is the balanced equation for the reaction as shown in the figure?
    a. $2NO + O_2 \rightarrow 2N_2O$
    b. $2NO + O_2 \rightarrow 2NO_2$
    c. $NO + O_2 \rightarrow 2NO_2$
    d. $N_2 + O_2 \rightarrow 2NO_2$

16. What scientific principle is reflected in a balanced equation?
    a. The law of conservation of mass
    b. The law of conservation of atoms
    c. The law of multiple proportions
    d. The law of definite proportions

17. Why can't you change the formula in order to balance a reaction?
    a. The number of atoms on the left should be equal to the atoms on the right of the arrow.
    b. The elements that combine have definite composition and fixed proportion of elements by mass.
    c. The elements have definite mass ratios.
    d. The molecule is indestructible.

18. Which equation does **NOT** conform with the Law of conservation of Mass?
    a. $2Al_{(l)} + 3BaO_{(s)} \rightarrow Al_2O_{3(s)} + 3Ba_{(l)}$
    b. $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(g)}$
    c. $Cl_{2(g)} + 2KBr_{(aq)} \rightarrow 2KCl_{(aq)} + Br_{2(l)}$
    d. $2\ Na_{(s)} + H_2O_{(l)} \rightarrow 2\ NaOH_{(s)} + H_{2(g)}$

19. Which set of compounds illustrates the law of multiple proportions?
    a. CH_4, CO, CCl_4
    b. N_2O, NO, NO_2
    c. NaCl, NaBr, NaI
    d. HF, F_2S, FCl_3

20. Which statement is true?
    a. When two elements form a series, they have the same composition.
    b. When two elements combine, there are always two compounds formed.
    c. When two elements combine, the first element is twice as much as the second.
    d. When two elements form a series of compounds, the ratios of the second element that combines with 1 g of the first element can be reduced into small whole numbers.

Key to answers on page 23.

Key to Answers

Pretest

1. b
2. d
3. b
4. a
5. c
6. d
7. b
8. c
9. b
10. d
11. c
12. d
13. c
14. b
15. a
16. b
17. b
18. b
19. b
20. d

Lesson 1

Self-Test 1.1

1. The mass of the system is 250 g. (The mass of the reactant is equal to the mass of the product.)
2. a does not conform with the Law of Conservation of Mass.
3. Reactants on the left and Products on the right side of the arrow.

Lesson 2

Activity 2.1

1. 63 g of Na
2. 0.71 g of hydrogen
3. 45.2 g of oxygen, 11.3 g of carbon

Self-Test 2.1

1. b
2. ClF_3
3. a. 16 g
   b. 96g O2

Lesson 3

Self-Test 3.1

1. b
2. d
3. a. 2:1
   b. The ratios are two whole numbers

Lesson 4

Self-Test 4.1

A. 1. $Al(NO_3)_3 + NaOH \rightarrow Al(OH)_3 + NaNO_3$
2. $Fe + H_2SO_4 \rightarrow Fe_2(SO_4)_3 + H_2$
3. $O_2 + CS_2 \rightarrow CO_2 + SO_2$

B. 1. $3Mg + N_2 \rightarrow Mg_3N_2$
2. $Cl_2 + 2KBr \rightarrow 2KCl + Br_2$
3. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

Posttest

1. c	6. b	11. b	16. a
2. c	7. a	12. a	17. b
3. d	8. c	13. d	18. d
4. d	9. d	14. c	19. b
5. a	10.a	15. b	20. d

References

Chang, R. (2002). *Chemistry*. (7th ed). USA:Mc-Graw Hill.

Smoot, R., Smith, C., Richard, G. & Price, J. (1995). *Merril Chemistry teacher wraparound edition*. NY: Mc-Graw Hill.

Padolina, M.C.D. (2000). *Chemistry: Fundamental concepts of chemistry 1*. UP Open University.

Zumdahl, S.S. (1998). *Chemical principles*. (3rd ed). NYC: Houghton Mifflin Company.