

Reflect

Imagine that you and three other classmates had enough supplies and the recipe to make one pepperoni pizza.

The recipe might include a ball of dough, a cup of pizza sauce, a cup of cheese, and 20 pieces of pepperoni. Although you could cut it into several pieces after you made the pizza, it would be impossible to turn one pizza into two pizzas of the same size without having more dough, sauce, cheese, and pepperoni. It would also be impossible to put a pepperoni pizza into the oven and have it turn into a mushroom pizza while it is baking.

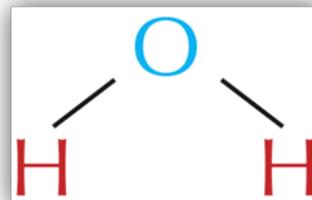
Just like a recipe, chemical reactions depend on the starting substances. How do you think you could describe the molecules involved in a reaction?



Matter cannot be created or destroyed—a mushroom pizza cannot be made with the ingredients for a pepperoni pizza.

Chemical formulas describe atoms held together by chemical bonds. A *compound* is a group of atoms of different elements joined together by sharing or transferring electrons. The atoms are then held together by a chemical attraction, called a *bond*. A *covalent compound* forms when two or more atoms combine by sharing electrons. The smallest unit of a covalent compound is called a *molecule*. You may be familiar with a molecule of water or carbon dioxide. An example of atoms held together by transferring electrons is sodium chloride. You may also have seen the chemical formulas for these compounds. A *chemical formula* is a representation of the smallest unit of a compound using elemental symbols to show the type of elements in the unit. *Subscripts* are used in the chemical formula to show the number of each type of element. Each element is represented in the chemical formula. The number of each type of element is represented by a subscript after the symbol.

Let's look at how to write the chemical formulas of some common substances. Some substances contain only two types of atoms. An example is sodium chloride, which you may also know as salt. Its chemical formula uses the symbols for sodium (Na) and chloride (Cl): NaCl. Water also contains two different atoms. Water is formed from hydrogen (H) and oxygen (O). It has the chemical formula H₂O. The subscript after the H in the formula is written to identify the number of hydrogen atoms in the molecule. So, a molecule of water contains two hydrogen atoms. When the smallest unit of a compound contains only one atom of an element, such as oxygen in water, or sodium and chloride in salt, a subscript is not needed.

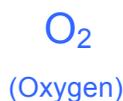
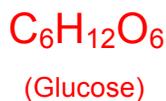


A molecule of water contains two atoms of hydrogen and one atom of oxygen. So its chemical formula is H₂O.

What Do You Think?

Some compounds may contain only a few atoms, such as sodium chloride and water. Others may contain multiple numbers and types of atoms. In some cases, atoms of the same element join together. Take a look at the chemical formulas of glucose (red), oxygen (blue), and carbon dioxide (green).

How do you know which elements are in each compound? Identify the types of elements and the number of atoms of each element in each compound below.



Chemical equations describe chemical reactions.

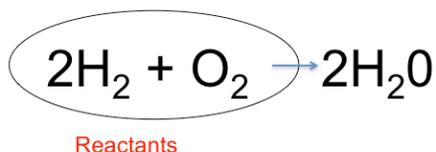
In a chemical reaction, molecules undergo a change. Atoms rearrange to form new substances. *Chemical equations* are written to show what happens to the atoms in a chemical reaction. A chemical equation shows the changes in the arrangement of atoms.

Let's look at the parts of a chemical equation.

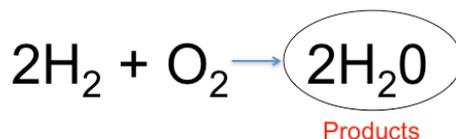
- **Reactants:** In a chemical equation the *reactants*, which are the starting substances, are usually written on the left side of the equation.
- **Products:** The *products* of the reaction are the substances that result from the reaction. Products are usually written on the right side of the equation.

The reactants are separated from the products by an arrow. The direction of the arrow points to the products in the reaction.

An example of a chemical reaction occurs when oxygen and hydrogen gas rearrange to form water. Oxygen gas (O_2) and hydrogen gas (H_2) are the reactants. Water (H_2O) is the product of the reaction. During the reaction, the atoms of the reactants rearrange into a new substance, the product. Here is the reaction with the reactants circled:



Here is the same reaction with the products circled:



In the reaction above, one molecule of O_2 reacts with two molecules of H_2 to form two molecules of water. You know this from the number written before each substance in the reaction. This number is called a coefficient. A *coefficient* is used in a chemical equation to show how many molecules take part in the reaction. H_2 and H_2O each has a coefficient of two. This means that two molecules of hydrogen gas are needed to form two molecules of water. A coefficient of “1” is never written in front of a substance. This is why there is no coefficient in front of the molecule O_2 . Only one molecule of oxygen gas is needed to form two molecules of water.

coefficient
indicates the number of molecules of an element

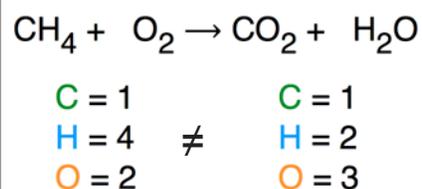
subscript
indicates the number of atoms in each molecule

Chemical equations obey the law of conservation of mass.

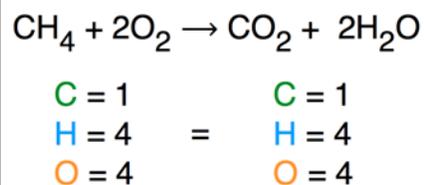
The *law of conservation of mass* states that mass is not created or destroyed in a chemical reaction. This law must be followed when you write a chemical equation. In the same way that you cannot create a mushroom pizza from a pepperoni pizza, the same atoms must be included in both the reactants and products of a chemical equation.

Each side of the chemical equation—reactants and products—must be balanced. This means that the number and type of elements on the side of the reactants must be the same as or equal to those on the products' side. Look at the equation in the top diagram at the right (“unbalanced”). This equation shows the reaction of methane (CH_4) with oxygen gas (O_2). The product is carbon dioxide (CO_2) and water (H_2O). This equation is not balanced. There is one carbon atom on each side of the equation, so the carbon atom is balanced. However, there are four atoms of hydrogen on the side of the reactants and only two atoms of hydrogen on the side of the products. There are also two atoms of oxygen on the reactants' side and three atoms of oxygen on the products' side of the equation.

Unbalanced:



Balanced:



In order to balance an equation, coefficients can be added or removed from a formula in a reaction. In the equation above, the hydrogen atoms can be balanced by adding a coefficient of 2 to H_2O . Then, the oxygen atoms can be balanced by adding a coefficient of 2 to O_2 . The bottom diagram at the left shows the balanced equation for this reaction.

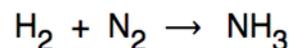
At this point, there are equal numbers of carbon, hydrogen, and oxygen atoms on both the reactants' and products' sides of the equation. There are 4 atoms of hydrogen, 1 atom of carbon, and 4 atoms of oxygen on both sides of the equation. To balance a reaction, you must confirm that all atoms are balanced. In this way, the equation is written so that it follows the law of conservation of mass.

Look Out!

When balancing equations, do not confuse the coefficient with the subscript of a formula. Remember that the coefficient describes the number of molecules of each substance that are present during a reaction. You can change this number to balance a chemical reaction. The subscript in a chemical formula determines the number of atoms that are present during a chemical reaction. This number cannot be changed to balance the chemical reaction.

In the unbalanced equation to the right, you can add coefficients to balance the equation but the subscripts do not change in any reaction. Fill in the blanks in the diagram for the unbalanced and balanced equations to show how adding coefficients balances the number of each type of atom. You can check your answers at the bottom of the following page.

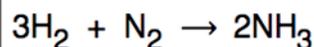
Unbalanced:



$$\text{H} = \underline{\quad\quad} \quad \text{H} = \underline{\quad\quad}$$

$$\text{N} = \underline{\quad\quad} \quad \neq \quad \text{N} = \underline{\quad\quad}$$

Balanced:



$$\text{H} = \underline{\quad\quad} \quad \text{H} = \underline{\quad\quad}$$

$$\text{N} = \underline{\quad\quad} \quad = \quad \text{N} = \underline{\quad\quad}$$

Getting Technical: Chemical Equations of Automobiles

One way that you are protected in an automobile crash is from the inflating of air bags. Upon impact, the air bag inflates very quickly and provides a cushion to the passenger to prevent injuries. The following chemical equation represents the primary reaction that causes the air bag to inflate:



NaN_3 is called sodium azide. It is a solid substance that is a reactant in the reaction. It is stored in a very small space such as the steering wheel of the car. When a crash occurs, the reactions begin. N_2 is known as nitrogen gas. The production of this gas causes the air bag to inflate. The nitrogen gas takes up a large volume that inflates the air bag.

It is important that scientists understand the chemical equation of this reaction. They must know how much sodium azide is needed to produce a quantity of nitrogen gas that will inflate the air bag properly.

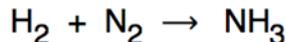


Air bags inflate from chemical reactions that can be described by chemical equations. Why do scientists need to understand these equations?

Look Out!

How many of each type of atom are present in the unbalanced and balanced chemical equations? Here are the answers:

Unbalanced:

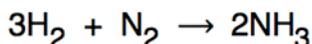


$$\text{H} = \underline{2} \quad \text{H} = \underline{3}$$

≠

$$\text{N} = \underline{2} \quad \text{N} = \underline{1}$$

Balanced:



$$\text{H} = \underline{6} \quad \text{H} = \underline{6}$$

=

$$\text{N} = \underline{2} \quad \text{N} = \underline{2}$$

What Do You Know?

Chemical equations can be written to describe chemical reactions. Look at the chemical equations in the table on the next page. For each equation, count the number of each type of atom in the reactants and the products. Then write "Balanced" or "Unbalanced" beside each equation.

| Chemical equation | Balanced or unbalanced? |
|---|-------------------------|
| $H_2 + I_2 \rightarrow 2HI$ (hydrogen reacts with iodine) | |
| $2Al + 3O_2 \rightarrow 2Al_2O_3$ (aluminum reacts with oxygen) | |
| $2Zn + 2HCl \rightarrow ZnCl_2 + H_2$ (zinc reacts with hydrogen chloride) | |

In each equation below, a blank line shows where one term is missing. The term may be an elemental symbol, a coefficient, or a subscript. Decide which term would balance the equation. Write the missing term in the second column. Then, determine the reactants (column 3) and products (column 4) of the reaction. Some reactions may have only one reactant or product, and other reactions may have multiple reactants or products. Write your answers in the spaces in the table. (The first reaction involves sodium chloride, not sodium, carbon, and iodine.)

| Chemical equation | Missing term | Reactant(s) | Product(s) |
|--|--------------|-------------|------------|
| $2NaCl \rightarrow 2Na + Cl$ _____ | | | |
| C ___ ₄ + $2O_2 \rightarrow CO_2 + 2H_2O$ | | | |
| 6 ___ $O_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ | | | |

Connecting With Your Child:

Cooking with Chemical Formulas and Equations

To help students learn more about chemical formulas and equations, work with your child to explain how equations are similar to a recipe that might be used while cooking. Interestingly, there are many different ways that chemical reactions and chemical equations are used in cooking. For example, when you bake a cake, one of the chemical reactions that occurs is the baking soda reacting with water to produce carbon dioxide gas. This gas produces the “holes” in the cake that give the cake its light, fluffy texture. A similar type of reaction occurs when baking soda is mixed with vinegar. Work with your child to investigate, either online or via textbook, the chemical formula of baking soda and vinegar. (Hint: The substance in vinegar that reacts is called acetic acid.) Then, work with your child to try to balance the reaction that occurs when baking soda and vinegar are mixed. Remember that carbon dioxide (CO_2) is a product of the reaction.

After your investigation, work closely with your child to perform this reaction. In a sink or outdoors, use a funnel to place one tablespoon of baking soda in a deflated balloon. Next, pour $\frac{1}{4}$ cup of water and $\frac{1}{4}$ cup of vinegar into a clear, empty, plastic water bottle. Carefully stretch the neck of the balloon over the lip of the bottle, being careful not to allow the baking soda to fall into the bottle. Finally, hold the bottle securely as you lift the end of the balloon so that the baking soda falls into the water and vinegar. The balloon will inflate from the carbon dioxide that is produced in the reaction.

After performing the reaction, discuss the following questions with your child:

- Why are chemical formulas used to represent vinegar and baking soda?
- Which elements are in the initial reactants—the baking soda and the vinegar? How does this compare to the elements in the products?
- How do you know a chemical reaction occurred? How do you know that carbon dioxide (a gas) formed in the reaction? Why is a chemical equation used to represent the reaction?