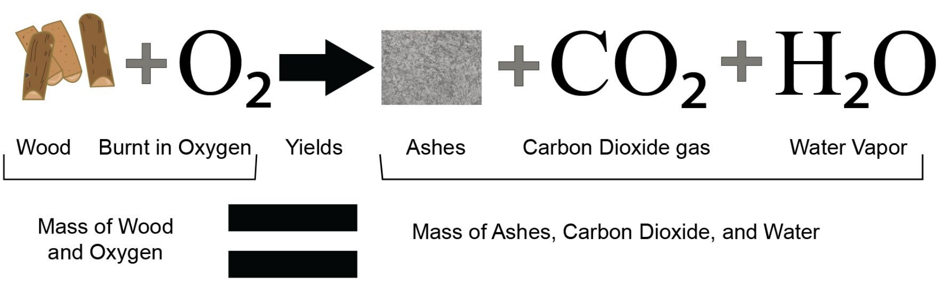
Modeling Conservation of Mass

Reflect

How is **mass** *conserved* (protected from loss)? Imagine an evening campfire. As the wood burns, you notice that the logs have become a small pile of ashes. What happened? Was the wood destroyed by the fire? A scientific principle called the **law of conservation of mass** states that matter is neither created nor destroyed. So, what happened to the wood? Think back. Did you observe smoke rising from the fire? When wood burns, atoms in the wood combine with oxygen atoms in the air in a chemical reaction called combustion. The products of this burning reaction are ashes as well as the carbon dioxide and water vapor in smoke. The gases escape into the air. We also know from the law of conservation of mass that the mass of the reactants must equal the mass of all the products. How does that work with the campfire?

mass – a measure of how much matter is present in a substance
law of conservation of mass – states that the mass of all reactants must equal the mass of all products and that matter is neither created nor destroyed

If you could measure the mass of the wood and oxygen before you started the fire and then measure the mass of the smoke and ashes after it burned, what would you find? The total mass of matter after the fire would be the same as the total mass of matter before the fire. Therefore, matter was neither created nor destroyed in the campfire; it just changed form. The same atoms that made up the materials before the reaction were simply rearranged to form the materials left after the reaction. Atoms are not created or destroyed in a chemical reaction. The **chemical equation** for the combustion reaction below shows the materials involved in this reaction.



chemical equation – chemical formulas and symbols written to represent a reaction

Chemical equations represent the conservation of mass in a chemical reaction.
In a chemical equation model, chemical formulas and symbols are used to represent a chemical reaction. The **reactants** are on the left side of the equation. The **products** are on the right side of the equation. According to the law of conservation of mass, the mass of all reactants must equal the mass of all products.

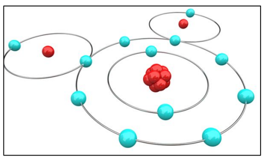
reactant – a substance that takes part in and undergoes change during a reaction
product – a substance produced during a chemical reaction

Chemical Compounds and Their Formulas

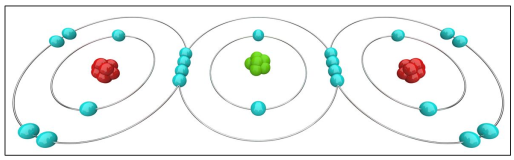
Chemical formulas describe the atoms held together by chemical bonds. A *compound* is a group of atoms of different elements joined together by the sharing or transferring of electrons. The atoms are held together by a chemical attraction called a *bond.*

- 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 (H_2O) or carbon dioxide (CO_2).

Covalent Bonds = Shared Electrons



H_2O
water molecule



CO_2
carbon dioxide molecule

- An *ionic compound*, such as sodium chloride (NaCl, or table salt), is an example of atoms held together by the transferring of electrons. You may have also seen the chemical formulas for these compounds.

Ionic Bonds = Transferred Electrons

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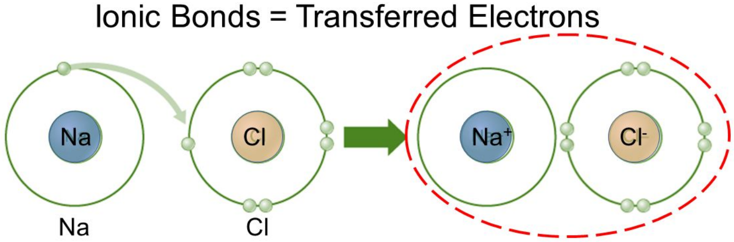


Na
Sodium atom

Cl
Chlorine atom

NaCl
Salt molecule

Try Now

A chemical formula is a representation of the smallest unit of a compound using elemental symbols to show the types of elements in the unit. *Subscripts* in the chemical formula are numbers written below and to the right of chemical symbols, showing the number of a specific type of atom present. If there is no subscript, only one atom of that element is represented in that compound. Using the chemical formula models on this page, write the formulas and the elements in each of the following three compounds as well as the number of atoms in each in parentheses.

Water:

Carbon dioxide:

Salt:

Reflect

Chemical equations obey the law of conservation of mass.
In each chemical reaction, the reactants and products must be balanced; therefore, in a **balanced chemical equation**, the number of each type of atom on the reactant side must equal the number of each type of atom on the product side. The only difference is that the atoms are rearranged to form new substances.

reactants → products

> **balanced chemical equation** – a symbolic representation of a chemical reaction in which both sides of the equation contain equivalent numbers of atoms of each element; the mass and the charge must be balanced on both sides of the reaction

For example, you know that two hydrogen atoms bond with one oxygen atom to form a molecule of water. The beginning chemical equation is as follows:

$$H_2 + O_2 \longrightarrow H_2O$$

Is this equation balanced? Not yet. There are two hydrogen atoms in the reactants and two hydrogen atoms in the product, but there are two oxygen atoms in the reactants, but only one on the product side. The equation is NOT balanced. You can change the number of atoms by adding more molecules, as indicated by the **coefficient**, number two, in front of the water molecule. That would give us the two needed oxygen atoms. However, in order to balance the four hydrogen atoms now created on the right, you would need two molecules of hydrogen gas on the left. So, you would write the coefficient, number two, in front of the hydrogen gas on the left.

$$2H_2 + O_2 \longrightarrow 2H_2O$$

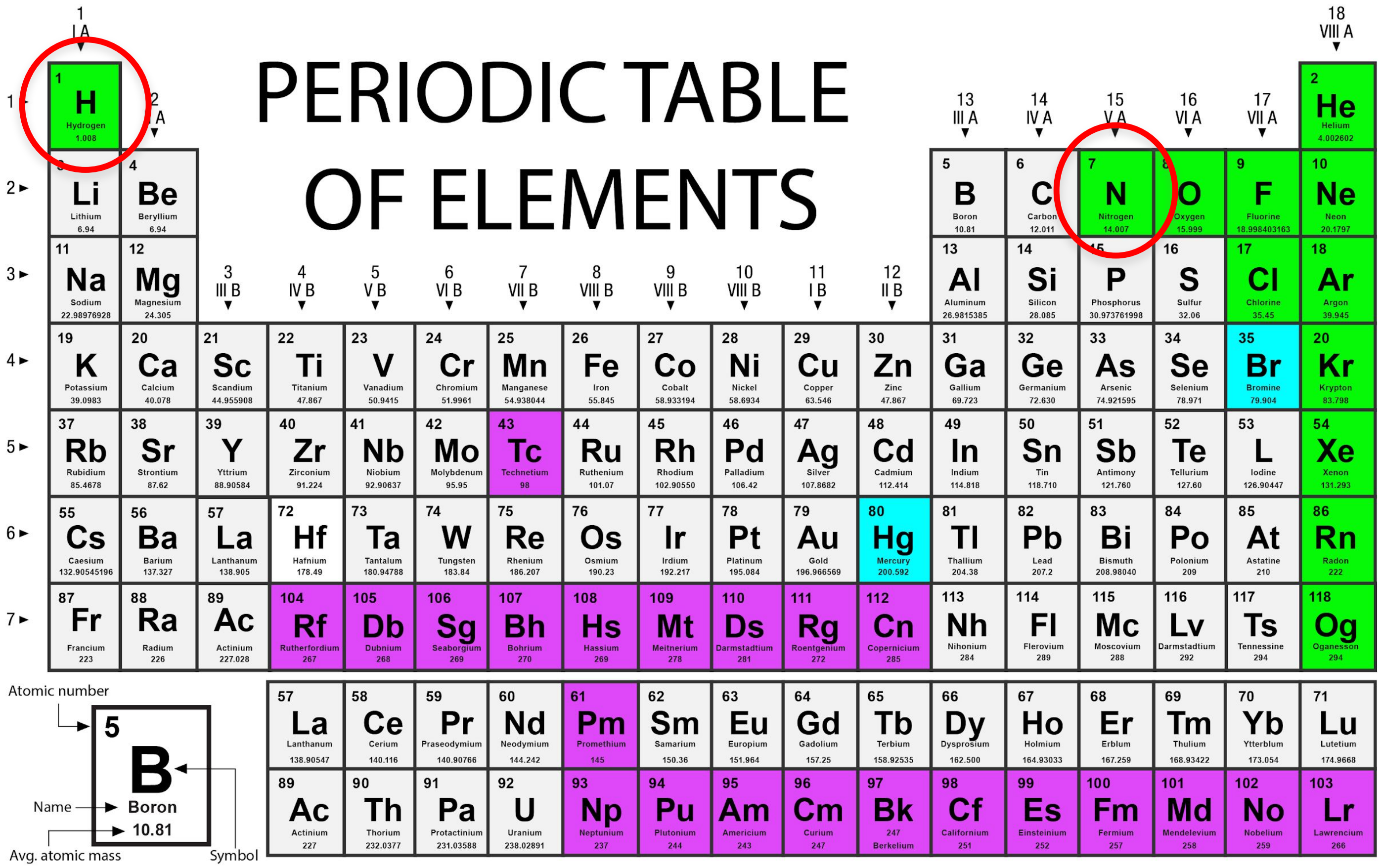
Coefficient Coefficient

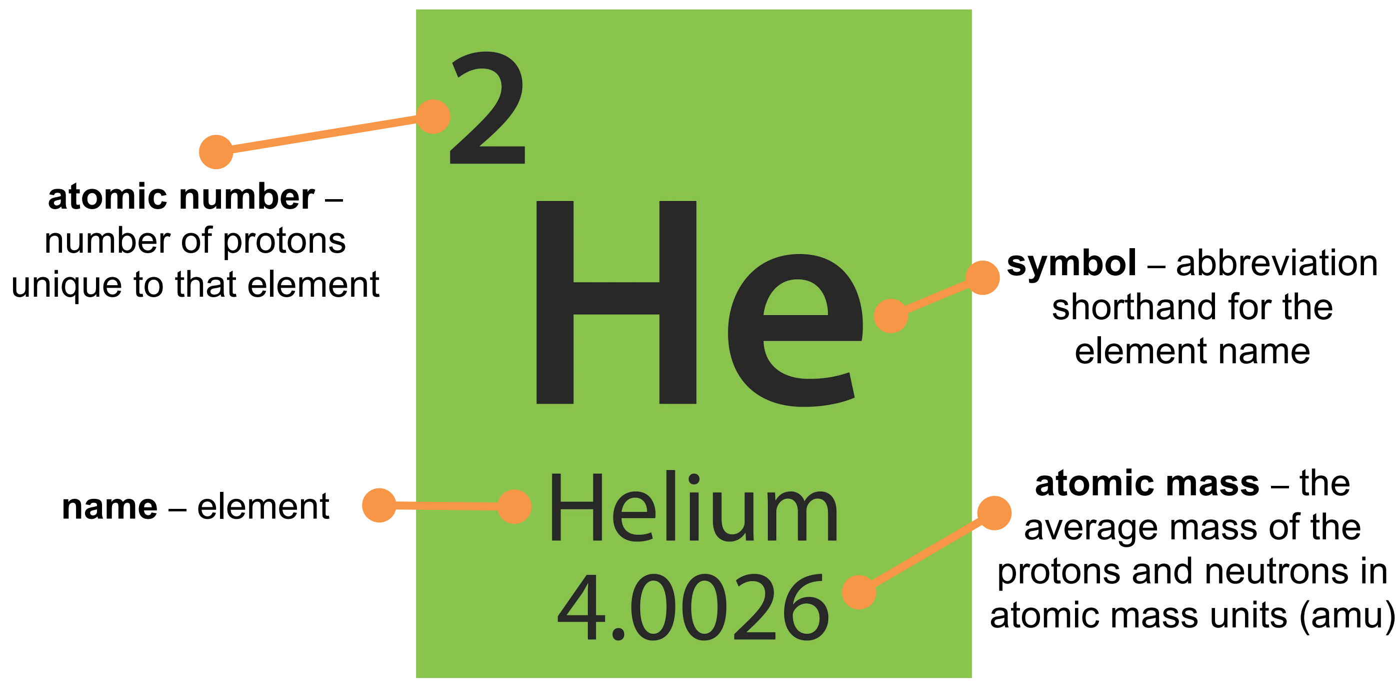
> **coefficient** – a number placed in front of a chemical symbol or formula in order to balance the equation

The coefficient number is multiplied times each of the subscripts to find out the total number of atoms in for each element in the compound. For example, on the left side of the above equation, $2H_2$ means 2 x H_2, or four hydrogen atoms, and O_2 means two oxygen atoms. On the right side of the equation above, $2H_2O$ means hydrogen has 2 x H_2, or four hydrogen atoms, and 2 x O, or two oxygen atoms. The four hydrogen and two oxygen atoms on the left balance with the four hydrogen and two oxygen atoms on the right. The chemical equation is balanced.

Using the Periodic Table to Find Mass
Use the periodic table of elements on page 4 to find the mass for each element in the compounds of the chemical equation that needs to be balanced on page 5.

The mass of hydrogen on the periodic table below is 1.0079 amu (atomic mass units), and the mass of nitrogen on the periodic table is 14.0067 amu.





Look at the unbalanced equation that follows. In order to calculate the mass of the reactants and products, follow the directions below.

$$\mathbf{H_2 + N_2 \rightarrow NH_3}$$

Count the number of each type of atoms on each side.
Then find the mass of each element on the periodic table.
Now multiply the total number of atoms on the reactant side by its mass.
Do this for each atom in the equation.
Now add the mass of all the reactants together to get the total mass.
Repeat this procedure on the product side.

*If the numbers of elements are not balanced, neither will the total mass be balanced.

	Reactants	Products
	$H_2 + N_2$ →	NH_3
Number of Hydrogen	2	3
Number of Nitrogen	2	1
Mass of Hydrogen	2 * 1.0079 = 2.0158	3 * 1.0079 = 3.0237
Mass of Nitrogen	2 * 14.0067 = 28.0134	1 * 14.0067= 14.0067
Total Mass	2.0158 + 28.0134 = **30.0292**	3.0237 + 14.0067 = **17.0304**

The mass of the reactants does not equal the mass of the products. The chemical equation as it is written here is not balanced. When balancing equations, you may change the coefficient but not the subscripts. Remember, the coefficient describes the number of molecules of each substance that is 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, because changing the subscript would change the identity of the compound.

In general, when balancing a chemical reaction, save any hydrogen or oxygen for the last atoms to balance. It will limit the amount of trial and error when balancing. If there are two nitrogen atoms on the reactant side and only one on the product side, you need to add a coefficient of two in front of NH_3. This gives you two nitrogen atoms, but now there are six hydrogen atoms (multiply the coefficients by the subscript to get the total number of atoms). Since there are six hydrogen atoms on the product side, putting a three in front of the H_2 on the reactant side will give you a total of six hydrogen atoms.

$$\underline{\mathbf{3}}H_2 + N_2 \rightarrow \underline{\mathbf{2}}NH_3$$

Let's look at the balanced equation (once you balance the equation, mass is conserved).

	Reactants	Products
	<u>**3**</u>H_2 + N_2 →	<u>**2**</u>NH_3
Number of Hydrogen	6	6
Number of Nitrogen	2	2
Mass of Hydrogen	6 * 1.0079 = 6.0474	6 * 1.0079 = 6.0474
Mass of Nitrogen	2 * 14.0067 = 28.0134	2 * 14.0067= 28.0134
Total Mass	6.0474 + 28.0134 = **34.0608**	6.0474 + 28.0134 = **34.0608**

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What Do You Think?

Let's look at another example. What coefficients do you need to balance this equation?

	Reactants	Products
	CH_4 + O_2 →	CO_2 + H_2O
Number of Carbon	1	1
Number of Hydrogen	4	2
Number of Oxygen	2	2 + 1 = 3
Mass of Carbon	1 * 12.0107 = 12.0107	1 * 12.0107 = 12.0107
Mass of Hydrogen	4 * 1.0079 = 4.0316	2 * 1.0079 = 2.0158
Mass of Oxygen	2 * 15.9994 = 31.9988	3 * 15.9994 = 47.9982
Total Mass	12.0107 + 4.0316 + 31.0088 = 47.0511	12.0107 + 2.0158 + 47.9982 = 62.0247

In the unbalanced equation above, the hydrogen atoms can be balanced by adding a coefficient of two to H_2O. Then the oxygen atoms can be balanced by adding a coefficient of two to O_2. The next page shows the new calculations for the balanced equation.

Reflect

Below is the balanced equation from the previous example with the correct mass calculations.

	Reactants	**Products**
	$CH_4 + \underline{\mathbf{2}}O_2$ →	$CO_2 + \underline{\mathbf{2}}H_2O$
Number of Carbon	1	1
Number of Hydrogen	4	4
Number of Oxygen	4	2 + 2 = 4
Mass of Carbon	1 * 12.0107 = 12.0107	1 * 12.0107 = 12.0107
Mass of Hydrogen	4 * 1.0079 = 4.0316	4 * 1.0079 = 4.0316
Mass of Oxygen	4 * 15.9994 = 63.9976	4 * 15.9994 = 63.9976
Total Mass	12.0107 + 4.0316 + 63.9976 = **80.0399**	12.0107 + 4.0316 + 63.9976 = **80.0399**

Look Out!

At this point, there are equal numbers of carbon, hydrogen, and oxygen atoms on both the reactant and product sides of the equation. There are four atoms of hydrogen, one atom of carbon, and four atoms of oxygen on both sides of the equation. Now the equation is written in a way that obeys the law of conservation of mass.

Getting Technical: Chemical Equations of Automobiles

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

$$2NaN_3 \rightarrow 2Na + 3N_2$$

NaN_3, or sodium azide, is the solid reactant in the chemical reaction and is stored in a very small space, such as the steering wheel of the car. When a crash occurs, the reaction begins. N_2 is known as nitrogen gas, which takes up a large volume that inflates the airbag. It is important for scientists to 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 airbag properly.

Try Now

Chemical equations can be written to describe chemical reactions. Look at the chemical equations in this table. 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. Then balance the equations below (if no coefficient is needed, leave the space blank). Verify each answer by making sure the mass of the reactants equals the mass of the products.

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)	

__K + __F_2 → __KF   mass of reactants/products = ___________

__H_2O_2 → __O_2 + __H_2O mass of reactants/products = ____________

___Ca + ____CuF_2 → ____CaF_2 + Cu   mass of reactants/products=_______