Step 3: Collecting the numbers from the various conversion factors and doing the arithmetic give us our answer.

$$\left(\frac{0.10 \times 1 \times 4 \times 14.01}{194.26 \times 1 \times 1}\right) \text{g N} = 0.029 \text{ g N}$$

Practice Exercise 6.6

How many grams of oxygen are present in a 0.10-g sample of adrenaline, a hormone secreted into the bloodstream in times of stress? The formula of adrenaline is $C_9H_{13}NO_3$.

Answer: 0.026 g O

6.6 WRITING AND BALANCING CHEMICAL EQUATIONS

A **chemical equation** *is a written statement that uses chemical symbols and chemical formulas instead of words to describe the changes that occur in a chemical reaction.* The following example shows the contrast between a word description of a chemical reaction and a chemical equation for the same reaction.

Word description:	Calcium sulfide reacts with water to produce calcium oxide and hydrogen sulfide.
Chemical equation:	$CaS + H_2O \longrightarrow CaO + H_2S$

In the same way that chemical symbols are considered the *letters* of chemical language, and chemical formulas are considered the *words* of the language, chemical equations can be considered the *sentences* of chemical language.

The substances present at the start of a chemical reaction are called *reactants.* A **reactant** *is a starting material in a chemical reaction that undergoes change in the chemical reaction.* As a chemical reaction proceeds, reactants are consumed (used up) and new materials with new chemical properties, called *products,* are produced. A **product** *is a substance produced as a result of the chemical reaction.*

Conventions Used in Writing Chemical Equations

Four conventions are used to write chemical equations.

In a chemical equation, the *reactants* are always written on the left side of the equation, and the *products* are always written on the right side of the equation.

1. *The correct formulas of the* ***reactants*** *are always written on the* ***left*** *side of the equation.*

$$CaS + H_2O \longrightarrow CaO + H_2S$$

2. *The correct formulas of the* ***products*** *are always written on the* ***right*** *side of the equation.*

$$CaS + H_2O \longrightarrow CaO + H_2S$$

3. *The reactants and products are separated by an arrow pointing toward the products.*

$$CaS + H_2O \longrightarrow CaO + H_2S$$

This arrow means "to produce."

4. *Plus signs are used to separate different reactants or different products.*

$$CaS + H_2O \longrightarrow CaO + H_2S$$

Plus signs on the reactant side of the equation mean "reacts with," and plus signs on the product side mean "and."

The diatomic elemental gases are the elements whose names end in *-gen* (hydrogen, oxygen, and nitrogen) or *-ine* (fluorine, chlorine, bromine, and iodine).

Atoms are neither created nor destroyed in a chemical reaction. The production of new substances in a chemical reaction results from the rearrangement of the existent groupings of atoms into new groupings. Because only rearrangement occurs, the products always contain the same number of atoms of each kind as do the reactants. This generalization is often referred to as the *law of conservation of mass.* The mass of the reactants and the mass of the products are the same, because both contain exactly the same number of atoms of each kind present.

The coefficients of a balanced equation represent numbers of molecules or formula units of various species involved in the chemical reaction.

In balancing a chemical equation, formula subscripts are *never changed.* You must use the formulas just as they are given. *The only thing you can do is add coefficients.*

A *valid* chemical equation must satisfy two conditions:

1. *It must be consistent with experimental facts.* Only the reactants and products that are actually involved in a reaction are shown in an equation. An accurate formula must be used for each of these substances. Elements in solid and liquid states are represented in equations by the chemical symbol for the element. Elements that are gases at room temperature are represented by the molecular formula denoting the form in which they actually occur in nature. The following monatomic, diatomic, and tetratomic elemental gases are known.

Monatomic:	He, Ne, Ar, Kr, Xe
Diatomic:	H_2, O_2, N_2, F_2, Cl_2, Br_2 (vapor), I_2 (vapor)
Tetraatomic:	P_4 (vapor), As_4 (vapor)*

2. *There must be the same number of atoms of each kind on both sides of the chemical equation.* Chemical equations that satisfy this condition are said to be balanced. A **balanced chemical equation** *is a chemical equation that has the same number of atoms of each element involved in the reaction on each side of the equation.* Because the conventions previously listed for writing equations do not guarantee that an equation will be balanced, we now consider procedures for balancing equations.

Guidelines for Balancing Chemical Equations

An unbalanced chemical equation is brought into balance by adding *coefficients* to the equation to adjust the number of reactant or product molecules present. An **equation coefficient** *is a number that is placed to the left of a chemical formula in a chemical equation; it changes the amount, but not the identity, of the substance.* In the notation $2H_2O$, the 2 on the left is a coefficient; $2H_2O$ means two molecules of H_2O, and $3H_2O$ means three molecules of H_2O. Thus equation coefficients tell how many molecules or formula units of a given substance are present.

The following is a balanced chemical equation, with the coefficients shown in color.

$$4NH_3 + 3O_2 \longrightarrow 2N_2 + 6H_2O$$

This balanced equation tells us that four NH_3 molecules react with three O_2 molecules to produce two N_2 molecules and six H_2O molecules.

A coefficient of 1 in a balanced equation is not explicitly written; it is considered to be understood. Both Na_2SO_4 and Na_2S have "understood coefficients" of 1 in the following balanced equation:

$$Na_2SO_4 + 2C \longrightarrow Na_2S + 2CO_2$$

An equation coefficient placed in front of a formula applies to the whole formula. By contrast, subscripts, which are also present in formulas, affect only parts of a formula.

Coefficient (affects both H and O)

$$2H_2O$$

Subscript (affects only H)

The preceding notation denotes two molecules of H_2O; it also denotes a total of four H atoms and two O atoms.

Let's look at the mechanics involved in determining the coefficients needed to balance a chemical equation. Suppose we want to balance the chemical equation

$$FeI_2 + Cl_2 \longrightarrow FeCl_3 + I_2$$

Step 1: *Examine the equation and pick one element to balance first.* It is often convenient to start with the compound that contains the greatest number of atoms, whether a reactant or a product, and focus on the element in that compound that has the greatest number of atoms. Using this guideline, we select $FeCl_3$ and the element chlorine within it.

*The four elements listed as vapors are not gases at room temperature but vaporize at slightly higher temperatures. The resultant vapors contain molecules with the formulas indicated.

We note that there are three chlorine atoms on the right side of the equation and two atoms of chlorine on the left (in Cl_2). For the chlorine atoms to balance, we will need six on each side; 6 is the lowest number that both 3 and 2 will divide into evenly. In order to obtain six atoms of chlorine on each side of the equation, we place the coefficient 3 in front of Cl_2 and the coefficient 2 in front of $FeCl_3$.

$$FeI_2 + 3Cl_2 \longrightarrow 2FeCl_3 + I_2$$

We now have six chlorine atoms on each side of the equation.

$$3Cl_2: \quad 3 \times 2 = 6$$
$$2FeCl_3: \quad 2 \times 3 = 6$$

Step 2: *Now pick a second element to balance.* We will balance the iron next. The number of iron atoms on the right side has already been set at 2 by the coefficient previously placed in front of $FeCl_3$. We will need two iron atoms on the reactant side of the equation instead of the one iron atom now present. This is accomplished by placing the coefficient 2 in front of FeI_2.

$$2FeI_2 + 3Cl_2 \longrightarrow 2FeCl_3 + I_2$$

It is always wise to pick, as the second element to balance, one whose amount is already set on one side of the equation by a previously determined coefficient. If we had chosen iodine as the second element to balance instead of iron, we would have run into problems. Because the coefficient for neither FeI_2 nor I_2 had been determined, we would have had no guidelines for deciding on the amount of iodine needed.

Step 3: *Now pick a third element to balance.* Only one element is left to balance—iodine. The number of iodine atoms on the left side of the equation is already set at four ($2FeI_2$). In order to obtain four iodine atoms on the right side of the equation, we place the coefficient 2 in front of I_2.

$$2FeI_2 + 3Cl_2 \longrightarrow 2FeCl_3 + 2I_2$$

The addition of the coefficient 2 in front of I_2 completes the balancing process; all the coefficients have been determined.

Step 4: *As a final check on the correctness of the balancing procedure, count atoms on each side of the equation.* The following table can be constructed from our balanced equation.

$$2FeI_2 + 3Cl_2 \longrightarrow 2FeCl_3 + 2I_2$$

Atom	Left Side	Right Side
Fe	$2 \times 1 = 2$	$2 \times 1 = 2$
I	$2 \times 2 = 4$	$2 \times 2 = 4$
Cl	$3 \times 2 = 6$	$2 \times 3 = 6$

All elements are in balance: two iron atoms on each side, four iodine atoms on each side, and six chlorine atoms on each side (see Figure 6.8).

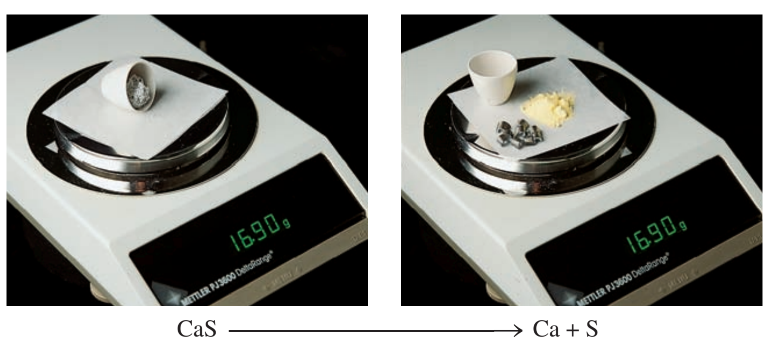

Figure 6.8 When 16.90 g of the compound CaS (left photo) is decomposed into its constituent elements, the Ca and S produced (right photo) has an identical mass of 16.90 grams. Because atoms are neither created nor destroyed in a chemical reaction, the masses of reactants and products in a chemical reaction are always equal.