8.3: Stoichiometry and the Molar Interpretation

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Learning Objectives

- Explain the meaning of the term "stoichiometry."
- Determine the relative amounts of each substance in chemical equations.

The previous section used an everyday example of an automobile factory to show the relationships between raw materials and products. In Chapter 7, we learned that chemical equations provide us with information about the types of particles that react to form products. Chemical equations also provide us with the relative number of particles and moles that react to form products. In this section, we will apply this knowledge to explore the quantitative relationships that exist between the amounts of reactants and products in a balanced chemical equation, also known as **stoichiometry**.

Stoichiometry, by definition, is the calculation of the quantities of reactants or products in a chemical reaction using the relationships found in a balanced chemical equation. The word stoichiometry is actually from two Greek words: $\sigma\tau o\iota\kappa\eta\iota o\nu$, which means "element", and $\mu\epsilon\tau\rho o\nu$, which means "measure".

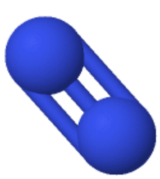
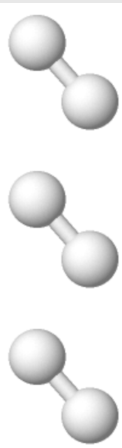
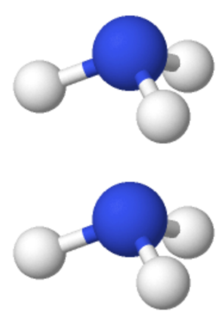
Interpreting Chemical Equations

The mole, as you remember, is a quantitative measure that is equivalent to Avogadro's number of particles. So how does this relate to the chemical equation? Consider the production of ammonia, NH_3, from nitrogen and hydrogen gases, an important industrial reaction called the Haber process, after German chemist Fritz Haber.

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

The coefficients used, as we have learned, tell us the relative amounts of each substance in the equation. So for every 1 unit of nitrogen, N_2, we have, we need to have 3 units of hydrogen, H_2. For every 1 dozen nitrogen molecules, we need 3 dozen hydrogen molecules. Because the "mole" is also a counting unit, we can interpret this equation in terms of moles, as well. For every 1 mole of nitrogen, we need 3 moles of hydrogen. Table 8.3.1 shows several ways of interpreting this chemical equation.

Table 8.3.1: Several Ways to Interpret a Chemical Equation

$N_2\,(g)$	+	$3\,H_2\,(g)$	→	$2\,NH_3\,(g)$
	+		→	
1 molecule N_2	+	3 molecules H_2	→	2 molecules NH_3
1 dozen molecules N_2	+	3 dozen molecules H_2	→	2 dozen molecules NH_3

$N_2\ (g)$	+	$3\ H_2\ (g)$	→	$2\ NH_3\ (g)$
1 mol N_2	+	3 mol H_2	→	2 mol NH_3
28.02 g N_2	+	6.048 g H_2	→	34.07 g NH_3

The most convenient unit for counting particles is the mole, since mole-sized quantities are measured in units of grams. This is the conventional method of interpreting any balanced chemical equation and is called the **molar interpretation** of a chemical equation.

⚡ Molar Interpretation

A method for interpreting balanced chemical equations in which the coefficients represent the number of moles of each substance.

Finally, if each mole quantity is converted to grams by using the molar mass, we can see that the law of conservation of mass is followed. 1 mole of nitrogen has a mass of 28.02 g, while 3 moles of hydrogen has a mass of 6.048 g, and 2 moles of ammonia has a mass of 34.07 g (slight difference due to rounding all masses to four significant figures). Mass and the number of atoms must be conserved in any chemical reaction.

✅ Example 8.3.1

The balanced chemical equation for the combustion of ethane, C_2H_6, is

$$2\ C_2H_6 + 7\ O_2 \rightarrow 4\ CO_2 + 6\ H_2O$$

A. Describe the equation in terms of the number of formula units or molecules.
B. Use a molar interpretation to describe the equation.

Solution

A. 2 molecules C_2H_6 react with 7 molecules O_2 to form 4 molecules CO_2 and 6 molecules H_2O.
B. 2 mol C_2H_6 react with 7 mol O_2 to form 4 mol CO_2 and 6 mol H_2O.

✏️ Exercise 8.3.1

Given the balanced chemical equation:

$$KBrO_3 + 6\ KI + 6\ HBr \rightarrow 7\ KBr + 3\ I_2 + 3\ H_2O$$

A. Describe the equation in terms of the number of formula units or molecules.
B. Use a molar interpretation to describe the equation.

Answer A

1 formula unit $KBrO_3$ reacts with 6 formula units KI and 6 molecules HBr to yield 7 formula units KBr, 3 molecules I_2, and 3 molecules H_2O.

Answer B

1 mol $KBrO_3$, 6 mol KI, and 6 mol HBr react together to yield 7 mol KBr, 3 mol I_2, and 3 mol H_2O.

Summary

- Stoichiometry is the calculation of the quantities of reactants or products in a chemical reaction using the relationships found in a balanced chemical equation.
- The coefficients in a balanced chemical equation represent the reacting ratios of the substances in the reaction.
- The coefficients of a balanced equation can be used to determine the ratio of moles of all substances in the reaction.