8.4: Molar Ratios and Mole-to-Mole Conversions

Learning Objectives

- Use a balanced chemical equation to determine molar relationships between substances.

The previous section described the molar interpretation of a balanced chemical equation. The balanced chemical equation:

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

tells us that 1 mol N_2 reacts with 3 mol H_2 to yield 2 mol NH_3. Referring back to the automobile factory analogy, this also means that several relationships and possible conversions may be identified. When the coefficients from the balanced chemical equation are used to represent conversion factors in terms of the number of moles, the relationships are called **molar ratios**.

Relationships	Molar Ratios	
1 mol N_2: 3 mol H_2	$\frac{1\ \text{mol}\ N_2}{3\ \text{mol}\ H_2}$	$\frac{3\ \text{mol}\ H_2}{1\ \text{mol}\ N_2}$
1 mol N_2: 2 mol NH_3	$\frac{1\ \text{mol}\ N_2}{2\ \text{mol}\ NH_3}$	$\frac{2\ \text{mol}\ NH_3}{1\ \text{mol}\ N_2}$
3 mol H_2: 2 mol NH_3	$\frac{3\ \text{mol}\ H_2}{2\ \text{mol}\ NH_3}$	$\frac{2\ \text{mol}\ NH_3}{3\ \text{mol}\ H_2}$

The molar ratios may then be used to convert between moles of one substance and moles of a different substance, in much the same way that we were able to convert between wheels and cars, bumpers and wheels, or cars and bumpers.

Suppose we wanted to know how many moles of H_2 were needed to completely react with 17.6 mol N_2. The appropriate molar ratio is used in such a manner that units cancel when calculating the the moles of H_2.

$$17.6\ \ \text{mol}\ \cancel{N_2} \times \frac{3\ \text{mol}\ H_2}{1\ \ \text{mol}\ \cancel{N_2}} = \boxed{52.8\ \text{mol}\ H_2}$$

Suppose we wanted to know how many moles of NH_3 could be made when 0.773 mol H_2 reacted with an excess of N_2. Once again, the appropriate molar ratio is used in such a manner that units cancel when calculating the the moles of NH_3. Note that the amount of N_2 is irrelevant, since it is present in excess.

$$0.773\ \ \text{mol}\ \cancel{H_2} \times \frac{2\ \text{mol}\ NH_3}{3\ \ \text{mol}\ \cancel{H_2}} = \boxed{0.515\ \text{mol}\ NH_3}$$

✅ Example 8.4.1

Identify all of the possible molar ratios for the balanced chemical equation:

$$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$$

Solution

Relationships	Molar Ratios	
2 mol H_2: 1 mol O_2	$\frac{2\ \text{mol}\ H_2}{1\ \text{mol}\ O_2}$	$\frac{1\ \text{mol}\ O_2}{2\ \text{mol}\ H_2}$

2 mol H_2: 2 mol H_2O	$\frac{\cancel{2} \text{ mol } H_2}{\cancel{2} \text{ mol } H_2O} = \frac{1 \text{ mol } H_2}{1 \text{ mol } H_2O}$	$\frac{\cancel{2} \text{ mol } H_2O}{\cancel{2} \text{ mol } H_2} = \frac{1 \text{ mol } H_2O}{1 \text{ mol } H_2}$
1 mol O_2: 2 mol H_2O	$\frac{1 \text{ mol } O_2}{2 \text{ mol } H_2O}$	$\frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2}$

✅ Example 8.4.2

Calculate the number of moles of hydrogen and oxygen required to make 3.34 mol of H_2O according to the balanced chemical equation:

$$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$$

Solution

The appropriate molar ratios (see Example 8.4.1) are used in such a manner that units cancel when calculating moles of H_2 and moles of O_2.

$$3.34\ \text{mol } \cancel{H_2O} \times \frac{1 \text{ mol } H_2}{1 \text{ mol } \cancel{H_2O}} = \boxed{3.34 \text{ mol } H_2}$$

$$3.34\ \text{mol } \cancel{H_2O} \times \frac{1 \text{ mol } O_2}{2 \text{ mol } \cancel{H_2O}} = \boxed{1.67 \text{ mol } O_2}$$

✏️ Exercise 8.4.1

A. Write a balanced chemical equation that shows the reaction between aluminum metal and oxygen gas to form an aluminum oxide solid.
B. Identify all of the possible molar ratios.

Answer A

$4\ Al\ (s) + 3\ O_2\ (g) \rightarrow 2\ Al_2O_3\ (s)$

Answer B

Relationships	Molar Ratios	
4 mol Al: 3 mol O_2	$\frac{4 \text{ mol Al}}{3 \text{ mol } O_2}$	$\frac{3 \text{ mol } O_2}{4 \text{ mol Al}}$
4 mol Al: 2 mol Al_2O_3	$\frac{\cancel{4} \text{ mol Al}}{\cancel{2} \text{ mol } Al_2O_3} = \frac{2 \text{ mol Al}}{1 \text{ mol } Al_2O_3}$	$\frac{\cancel{2} \text{ mol } Al_2O_3}{\cancel{4} \text{ mol Al}} = \frac{1 \text{ mol } Al_2O_3}{2 \text{ mol Al}}$
3 mol O_2: 2 mol Al_2O_3	$\frac{3 \text{ mol } O_2}{2 \text{ mol } Al_2O_3}$	$\frac{2 \text{ mol } Al_2O_3}{3 \text{ mol } O_2}$

✏️ Exercise 8.4.2

Given the balanced chemical equation:

$$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$$

A. How many moles of O_2 are needed to completely react with 3.08 mol C_8H_{18}?

B. How many moles of C_8H_{18} will react when 7.7 mol CO_2 are produced?

Answer A

38.5 mol O_2

Answer B

0.96 mol C_8H_{18}

Summary

- The balanced chemical reaction can be used to determine molar relationships between substances.