Stoichiometric Calculations: Amounts of Reactants and Products

The coefficients in a chemical equation represent *numbers* of molecules, not masses of molecules. However, when a reaction is to be carried out in the lab, the amounts of substances needed can't be determined by counting molecules directly. Counting is always done by weighing.

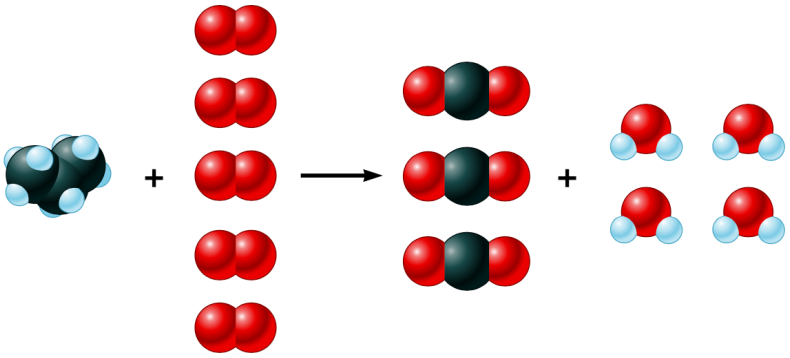
Stoichiometry is the study of the quantitative relationships between the amounts of reactants used and products formed by a chemical reaction.

To see how stoichiometry works, consider the combustion of propane. We will consider the question: *What mass of oxygen will react completely with 96.1 g of propane?*

The first step in any stoichiometry problem is to write the balanced chemical equation for the reaction. In this case, the balanced equation is

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

This can be visualized as



This equation means that 1 mole of C_3H_8 reacts with 5 moles of O_2 to produce 3 moles of CO_2 and 4 moles of H_2O.

To use this equation to find the masses of reactants and products, we must be able to convert between masses and moles of substances. Thus, we must first ask: *How many moles of propane are present in 96.1 g of propane?*

$$96.1\ g\ C_3H_8 \times \frac{1\ mol\ C_3H_8}{44.1\ g\ C_3H_8} = 2.18\ mol\ C_3H_8$$

Next, we must take into account the fact that each mole of propane reacts with 5 moles of oxygen. The best way to do this is to use the balanced equation to construct a **mole ratio**. In this case, the mole ratio we need is

$$\frac{5\ mol\ O_2}{1\ mol\ C_3H_8}$$

Multiplying the number of moles of C_3H_8 by this factor gives the number of moles of O_2 required:

$$2.18\ mol\ C_3H_8 \times \frac{5\ mol\ O_2}{1\ mol\ C_3H_8} = 10.9\ mol\ O_2$$

Notice that the mole ratio is set up so that the moles of C_3H_8 cancel out.

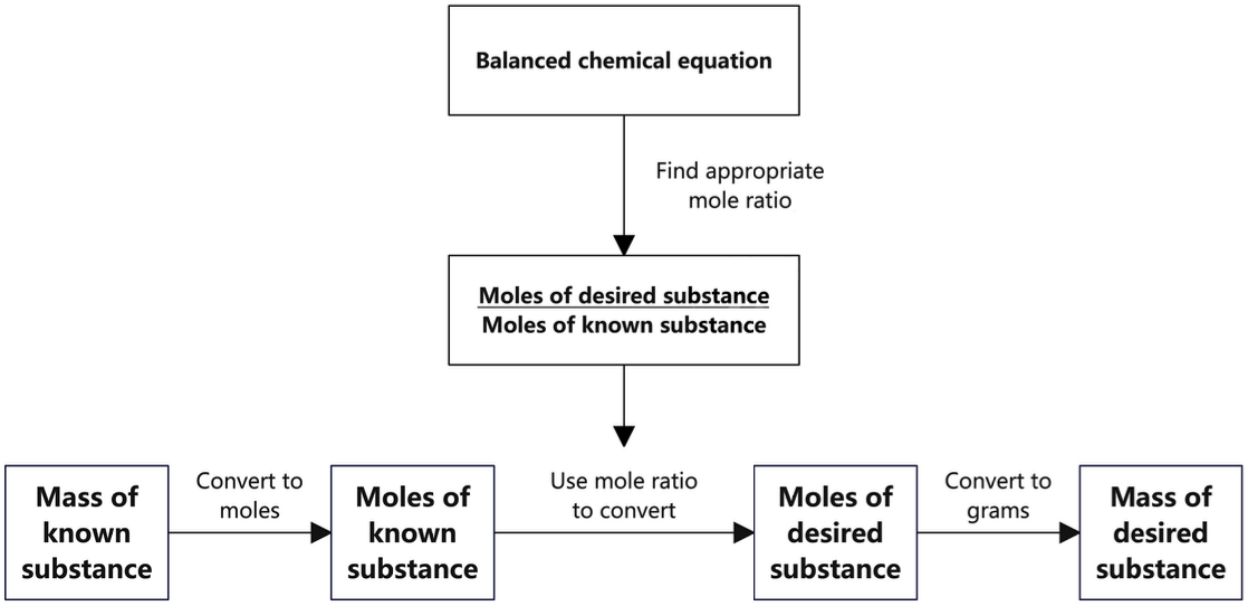
Since the original question asked for the mass of oxygen needed to react with 96.1 g of propane, the last step is to convert the 10.9 moles of O_2 to *grams*.

$$10.9\ mol\ O_2 \times \frac{32.0\ g\ O_2}{1\ mol\ O_2} = 349\ g\ O_2$$

Example 1
What mass of carbon dioxide is produced when 96.1 g of propane are combusted with oxygen?

Problem Solving Strategy
Calculating Masses of Reactants and Products in Chemical Reactions

1. Write the balanced equation for the reaction.
2. Convert the known mass of the reactant or product to moles of that substance.
3. Use the balanced equation to set up the appropriate mole ratios.
4. Use the appropriate mole ratios to calculate the number of moles of the desired reactant or product.
5. Convert from moles back to grams if required by the problem.



Example 2

Determine the mass of sodium chloride or table salt ($NaCl$) produced when 1.25 mol of chlorine gas reacts vigorously with sodium.

Example 3

Ammonium nitrate (NH_4NO_3), an important fertilizer, produces N_2O gas and H_2O when it decomposes. Determine the mass of water produced from the decomposition of $25\ g$ of solid ammonium nitrate.

Stoichiometry Worksheet #1

1. Sulfuric acid is formed when sulfur dioxide reacts with oxygen and water. Write the balanced chemical equation for the reaction. If 12.5 *mol* SO_2 reacts, how many *mol* H_2SO_4 can be produced? How many *mol* O_2 is needed?

2. A reaction between methane and sulfur produces carbon disulfide (CS_2), a liquid often used in the production of cellophane.

$$\_\_\_\_ CH_4(g) + \_\_\_\_ S_8(s) \rightarrow \_\_\_\_ CS_2(l) + \_\_\_\_ H_2S(g)$$

   a) Balance the equation.

   b) Calculate the *mol* CS_2 produced when 1.5 *mol* S_8 is used.

   c) How many *mol* H_2S is produced?

3. Titanium is a transition metal used in many alloys because it is extremely strong and lightweight. Titanium tetrachloride ($TiCl_4$) is extracted from titanium oxide using chlorine and coke (carbon).

$$TiO_2(s) + C(s) + 2Cl_2(g) \rightarrow TiCl_4(s) + CO_2(g)$$

   If you begin with 1.25 *mol* TiO_2, what mass of Cl_2 is needed?

4. Sodium chloride is decomposed into the elements sodium and chlorine by means of electrical energy. How many grams of chlorine gas can be obtained from 2.5 *mol NaCl* ?

5. One in a series of reactions that inflate air bags in automobiles is the decomposition of sodium azide (NaN_3).

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

   Determine the mass of N_2 produced if 100 *g* NaN_3 is decomposed.

6. In the formation of acid rain, sulfur dioxide reacts with oxygen and water in the air to form sulfuric acid. Write the balanced chemical equation for the reaction. If 2.5 *g* SO_2 react with excess oxygen and water, how many grams of H_2SO_4 are produced?