Sample Problem 8B
Mole-mass stoichiometry

Because oxygen is already given in a mole amount, the molar mass of O₂ is unnecessary.

1. List
   - Amount of O₂ used each minute: 1.03 x 10⁻³ mol O₂
   - Molar mass of Ca₉H₁₆O₈: 176 g/mol
   - Molar ratio of 1 mol Ca₉H₁₆O₈ is 8 mol O₂
   - Mass of glucose used each minute: ?

2. Set up
   - First, analyze what needs to be done to get the answer. You are given moles of oxygen, so you can convert to moles of glucose using the mole ratio. Then, you can use the molar mass to determine the mass in grams of the glucose.
   
   \[
   \text{mass of glucose} = \frac{1.03 \times 10^{-3} \text{ mol O}_2 \times 8 \text{ mol Ca}_9\text{H}_{16}\text{O}_8}{1 \text{ mol O}_2} \times 176 \text{ g Ca}_9\text{H}_{16}\text{O}_8
   \]

3. Estimate and calculate
   - Before calculating, round off the numbers in the setup to make an estimate.
   
   \[
   0.1 \times 1 \times \frac{176}{1} = 0.3
   \]

   Then use your calculator to work through the setup. Be sure to round to the correct number of significant figures, which is three.

   Answer to three significant figures:
   
   \[
   1.03 \times 10^{-3} \text{ mol O}_2 \times 8 \text{ mol Ca}_9\text{H}_{16}\text{O}_8 \times \frac{176 \text{ g Ca}_9\text{H}_{16}\text{O}_8}{1 \text{ mol Ca}_9\text{H}_{16}\text{O}_8} = 0.208 \text{ g Ca}_9\text{H}_{16}\text{O}_8
   \]

Practice 8B
1. Use the information in Sample Problem 8B to determine how many grams of carbon dioxide would be produced each minute.
2. Use the information in Sample Problem 8B to determine how many grams of water would be produced each minute.

Using density with stoichiometry

Remember that the key to solving any reaction stoichiometry problem is to always calculate in moles. Once the number of moles is determined, convert factors such as molar mass can be used to convert from the mass in grams. Similarly, once the mass is known, the density of a substance can be used to convert from mass to volume. Recall from Chapter 2 that density is defined as the mass of a substance per unit volume, expressed mathematically as \(D = \frac{m}{V}\). Once again, the key is to use the density value to set up a conversion factor that will cancel the units in the measurement you have and leave the units of the measurement for the answer, as shown in Sample Problem 8C. Once more, you already know everything you need to solve such problems from your study of concepts earlier in the book.
Sample Problem
8A
Mass-mass stoichiometry

Problem
8C
Stoichiometry calculations with density

* List what you know
- amount of CO₂: 25.0 mol CO₂
- density of H₂O: 1.00 g/mL
- molar mass of H₂O: 18.02 g/mol
- molar ratio: 1 mol CO₂ : 1 mol H₂O
- volume of H₂O produced: 9 mL

* Set up
- First, analyze what needs to be done to get the answer. You are given moles of CO₂, so you can convert to moles of water using the molar ratio. Then, use the molar mass to find out the mass of water.

  \[
  \text{mass of H}_2\text{O} = 25.0 \text{ mol CO}_2 \times \frac{1 \text{ mol H}_2\text{O}}{1 \text{ mol CO}_2} \times 18.02 \text{ g H}_2\text{O} = 450.5 \text{ g H}_2\text{O}
  \]

- Next, convert from mass of H₂O to volume of H₂O using the density as the conversion factor. The correct conversion factor will have g H₂O in the denominator and mL H₂O in the numerator.

  \[
  \text{volume of H}_2\text{O} = \frac{450.5 \text{ g H}_2\text{O}}{1 \text{ g H}_2\text{O}} \times 1 \text{ mL H}_2\text{O} = 900 \text{ mL H}_2\text{O}
  \]

* Estimate and calculate
- Before calculating, round off the numbers in the setup to make an estimate.

  \[
  25 \times 1 \times 18 \div 1 = 300
  \]

- Then, use your calculator to work through the setup. Be sure to round to the correct number of significant figures, which is three.

  \[
  \frac{450.5 \text{ g H}_2\text{O}}{1 \text{ g H}_2\text{O}} \times 1 \text{ mL H}_2\text{O} = 0.900 \text{ mL H}_2\text{O}
  \]

Practice 8C

1. The reaction that causes cake batter to rise involves the production of CO₂ from NaHCO₃. How many liters of CO₂ gas will be created when 15.0 g NaHCO₃ are heated? (Note: at baking temperature, the density of CO₂ is about 1.10 g/L.)

  \[
  2\text{NaHCO}_3(s) \rightarrow \text{CO}_2(g) + \text{Na}_2\text{CO}_3(s) + \text{H}_2\text{O}(g)
  \]

2. A common ingredient used in some sunscreens is p-amino benzene acid, or PABA, which can absorb some of the ultraviolet radiation of the sun. It is made from p-nitrobenzoic acid, which is a solid with a density of 1.58 g/mL. The reaction actually has several intermediate steps but can be summarized as shown below. What is the maximum mass of PABA that can be made from 500 mL of p-nitrobenzoic acid crystals?
8-1 Practice

**Mass-Mass Stoichiometry**

Use the problem-solving strategies below to solve items 1–10 in Section 8-1, 1–7 in Section 8-2, and 1–12 in Section 8-3.

*List what you know*
- List all data given in the problem and identify what you are being asked to determine.

*Set up the problem*
- Reread the problem to note if there is information missing.
- Write the balanced chemical equation.
- Decide what conversion factors or algebraic equations to use and set up the equation.

*Estimate and calculate*
- Before calculating, estimate an answer.
- Calculate the exact answer.
- Is your calculated value close to the estimate? Does the answer make sense?
- Check your work.

1. What mass in grams of sodium nitrate, $\text{NaNO}_3$, is produced if 20.0 g of sodium azide, $\text{NaN}_3$, in a dilute aqueous solution are reacted with excess silver nitrate, $\text{AgNO}_3$?

Answer

2. What mass in grams of sodium carbonate, $\text{Na}_2\text{CO}_3$, is produced if 50.0 g of sodium oxide, $\text{Na}_2\text{O}$, are reacted with excess carbon monoxide, CO, according to the following chemical equation? (Hint: see Sample Problem 8A.)

$$2\text{Na}_2\text{O}(s) + \text{CO}(g) \rightarrow \text{Na}_2\text{CO}_3(s) + \text{Na}(s)$$

Answer
Mole-Mass Stoichiometry

5. How many moles of carbon dioxide gas can be produced if 25.0 g of Cr₂(CO₃)₃ are reacted with excess nitric acid, HNO₃, according to the following chemical equation? (Hint: see Sample Problem 8B.)

\[ \text{Cr}_2(\text{CO}_3)_3(s) + 6\text{HNO}_3(aq) \rightarrow 2\text{Cr(NO}_3)_3(aq) + 3\text{H}_2\text{O}(l) + 3\text{CO}_2(g) \]

6. What mass in grams of carbon dioxide is produced if 85.0 mol of magnesium carbonate, MgCO₃, are heated and allowed to decompose to magnesium oxide and carbon dioxide?

\[ \text{MgCO}_3(s) \overset{\text{heat}}{\rightarrow} \text{MgO}(s) + \text{CO}_2(g) \]

Finding the Limiting Reactant

1. If 100. g of zinc metal and 100. g of copper(II) nitrate react, how many grams of copper metal will be produced?

2. 100. g of Ca(OH)₂ are added to a beaker containing 50.0 g of HCl dissolved in water. All of the calcium hydroxide be neutralized?

6. 25.0 g of carbon react with excess water. How many grams of methane can be expected if the percent yield for this reaction is 90.0%?

\[ 2\text{C}(s) + 2\text{H}_2\text{O}(l) \rightarrow \]

3. How many liters of oxygen evolve from the decomposition of 850. g of KClO₃? The density of O₂ is 1.429 g/L. (Hint: see Sample Problem 8G.)

\[ 2\text{KClO}_3(s) \rightarrow 2\text{KCl}(s) + 3\text{O}_2(g) \]
3.7 Limiting Reactants

We have determined that the reaction to be followed is: 

\[ \text{Reactant 1} + \text{Reactant 2} \rightarrow \text{Product} \]

From this, we can calculate the limiting reagent by comparing the moles of each reactant to the stoichiometry of the reaction. The limiting reagent is the reactant that is completely consumed first, limiting the amount of product that can be formed. The excess reagent is the one that remains in excess after the reaction is complete.

### Calculation

1. **Moles of Reactant 1:** 
   \[ \text{Moles} = \frac{\text{mass of reactant}}{\text{molar mass of reactant}} \]

2. **Moles of Reactant 2:** 
   \[ \text{Moles} = \frac{\text{mass of reactant}}{\text{molar mass of reactant}} \]

3. **Stoichiometry:** 
   - Reactant 1: \( \text{X} \)
   - Reactant 2: \( \text{Y} \)

4. **Limiting Reagent:** 
   - If the moles of Reactant 1 times its stoichiometric coefficient is less than the moles of Reactant 2 times its stoichiometric coefficient, Reactant 1 is the limiting reagent.
   - If the moles of Reactant 2 times its stoichiometric coefficient is less than the moles of Reactant 1 times its stoichiometric coefficient, Reactant 2 is the limiting reagent.

5. **Calculation Example:** 
   - Reactant 1: \( \text{X} \) \( \times \) \( \text{1 mol} \) = \( \text{X mol} \)
   - Reactant 2: \( \text{Y} \) \( \times \) \( \text{2 mol} \) = \( \text{2Y mol} \)

   If \( \text{X} \) < \( \frac{1}{2} \text{Y} \), then Reactant 1 is limiting.

### Conclusion

By determining the limiting reagent, we can predict the maximum yield of the product and adjust the reaction conditions accordingly.