Lesson 16: Theoretical Yield, Experimental Yield, and Percent Yield

Box 1:

2 flags + 1 pole + 4 wheels + 1 car body → 1 car

1. If you had 62 flags, 37 poles, 102 wheels, and 30 car bodies, how many complete toy cars could you make? What reactant is limiting?

2. $\text{SiO}_2 (s) + 4\text{HF} (g) \rightarrow \text{SiF}_4 (g) + 2\text{H}_2\text{O} (l)$
   If you started with 0.910 mol of silicon dioxide and 3.51 mol of HF, what is the limiting reactant? What is the theoretical yield of water (in moles)?

3. Which property can be defined as the ability of a substance to form an aqueous solution?
   A) conductivity  B) malleability
   C) melting point  D) solubility

4. Which statement describes a chemical property of silver?
   A) Silver can be flattened into sheets.
   B) Silver conducts electricity and heat.
   C) Silver tarnishes by combining with oxygen to form silver oxide.
   D) Silver can be drawn into a wire.
REVIEW: Limiting and Excess Reactants

One reactant almost always limits the amount of product produced in a reaction. Once one of the reactant is used up, ____________________________________________________________________________________.

The substance that is used up first is the _________________________________.

Identifying the limiting reactant: calculate the _________________________________. The limiting reactant has the smaller equivalent (you will run out of that reactant first).

NOTE: The “amount that you start with” must be in number of compounds or moles. If you’re given an amount in grams, you have to convert it to moles first.

1. \[ \text{SiO}_2 + \text{HF} \rightarrow 2 \text{SiF}_4 + 2 \text{H}_2\text{O} \]

   \begin{align*}
   \text{SiO}_2 & \quad \text{HF} \\
   4.5 \text{ mol} & \quad 6.0 \text{ mol}
   \end{align*}

   Amount that you start with
   \begin{align*}
   \text{Co-efficient of the reactant}
   \end{align*}

   These numbers are called "molar equivalents".

2. \[ \text{N}_2\text{H}_4 \text{ (l)} + 2 \text{H}_2\text{O}_2 \text{ (l)} \rightarrow \text{N}_2 \text{ (g)} + 4 \text{H}_2\text{O} \text{ (g)} \]

   \begin{align*}
   \text{N}_2\text{H}_4 & \quad \text{H}_2\text{O}_2 \\
   0.750 \text{ mol} & \quad 5.2 \text{ mol}
   \end{align*}

   Amount that you start with
   \begin{align*}
   \text{Co-efficient of the reactant}
   \end{align*}

   These numbers are called "molar equivalents".
3. Methanol, CH₃OH is the simplest of alcohols. It is synthesized by the reaction of hydrogen and carbon monoxide.

\[ \text{CO (g)} + 2\text{H}_2 (g) \rightarrow \text{CH}_3\text{OH} \]

a. If 500 mol CO and 750 mol H₂ are present, which is the limiting reactant?

b. How many moles of the excess reactant remain unchanged?

c. How many moles of CH₃OH are formed?

4. The black oxide of iron, Fe₃O₄, occurs in nature as the mineral magnetite. The substance can also be used in the laboratory by the reaction between red-hot iron and steam according to the following reaction:

\[ 3\text{Fe(s)} + 4\text{H}_2\text{O (g)} \rightarrow \text{Fe}_3\text{O}_4(s) + 4\text{H}_2 (g) \]

a. When 36 g of H₂O are mixed with 67.0 g Fe, which is the limiting reactant?

b. What mass in grams of black iron oxide is produced?

c. What mass in grams of excess reactant remains when the reaction is completed?
THEORETICAL YIELD
- Theoretical yield is the __________________________________________________________________________
  when the limiting reactant is completely consumed.
- Theoretical yield __________________________________________________________________________
  __________________________________________________________________________________________________________________________________________________
  and is calculated using stoichiometry __________________________________________________________________________
  ____________________________________________________________________________________________.
- Just as the __________________________________________________________________________ allows us to calculate limiting and excess reactants and
  masses, we can also __________________________________________________________________________ the mass of products in any given reaction.
- The theoretical yield represents __________________________________________________________________________
  ____________________________________________________________________________________________.

ACTUAL YIELD
- The __________________________________________________________________________________________obtained from a reaction
  is called the actual yield (or experimental yield) of that product.

PERCENT YIELD
- Comparing the theoretical and actual yield helps chemists determine the reaction’s
  __________________________________________________________________________.
- The percent yield represents the _______________ of the actual yield to the theoretical yield.

\[
\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100
\]
1. One mole of methane combusts with 2 moles of oxygen to produce 1 mole of carbon dioxide and 2 moles of water.
\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]

a) How many grams of H\textsubscript{2}O are expected when 8.00 grams of CH\textsubscript{4} reacts with an excess of O\textsubscript{2}?

b) If only 17.0 grams of H\textsubscript{2}O are produced, what is the percent yield of this reaction?

2. Chlorobenzene, C\textsubscript{6}H\textsubscript{5}Cl, is used in the production of many important chemicals, such as aspirin, dyes, and disinfectants. One industrial method of preparing chlorobenzene is to react benzene, C\textsubscript{6}H\textsubscript{6}, with chlorine, as represented by the following equation.
\[ \text{C}_6\text{H}_6 (l) + \text{Cl}_2 (g) \rightarrow \text{C}_6\text{H}_5\text{Cl} (l) + \text{HCl} (g) \]

Starting amounts: 52.6 g 60.2 g

a) Which is the limiting reactant?

b) Determine the amount of excess reactant reacted and amount remaining.

c) Calculate the theoretical yield of product chlorobenzene.

d) If 73.9 g of chlorobenzene was actually produced, what was the percent yield?
MORE PRACTICE:

3. 300.0g ethane gas (C₂H₆) reacts with 650.0g chlorine gas to produce chloroethane (C₂H₅Cl) and hydrochloric acid.

   a) Identify the limiting and excess reactant

   b) Determine the amount of excess reactant reacted and remaining

   c) Calculate the theoretical yield of product

   d) Calculate the percent yield given the actual yield
4. 582 g of ammonia vapor and 655g methane gas react in excess oxygen to produce gaseous hydrogen cyanide (HCN) and steam.

a) Identify the limiting and excess reactant

b) Determine the amount of excess reactant reacted and remaining

c) Calculate the theoretical yield of product

d) Calculate the actual yield given the percent yield is 89.6%
5. 2.50g of bornite (Cu$_3$FeS$_3$) ore react with excess oxygen to produce copper, iron (II) oxide, and sulfur dioxide.

   a) Determine the amount of excess reactant reacted

   b) Calculate the theoretical yield of each product

   c) Calculate the actual yield given the percent yield of 65.2%.

6. 56.7g of liquid propane (C$_3$H$_8$) are combusted in excess oxygen.

   a) Determine the amount of excess reactant reacted (how much oxygen was necessary to combust all the propane)?

   b) Calculate the theoretical yield of product
7. 9.8g of liquid octane (C₈H₁₈) and 42.6g of oxygen are available as reactants in a combustion reaction. Combustion reactions produce water and carbon dioxide as products.

a) Identify the limiting and excess reactant

b) Determine the amount of excess reactant reacted.

c) Calculate the theoretical yield of product.

d) Calculate the actual yield given the percent yield of 95.5%.
Box 2:

1. What is molar mass?

2. What is its role in reaction stoichiometry?

3. Sulfuric acid (H$_2$SO$_4$) reacts with sodium hydroxide to form sodium sulfate and water.
   a. Write the balanced equation.

   b. If 335 g of sodium hydroxide reacted in excess of sulfuric acid, how many grams of sodium sulfate would be produced?

4. Write the following chemical formulas:
   a. iron (II) nitrite
   b. lead (III) phosphate

Box 3:

1. Distinguish between ideal and real stoichiometric calculations.

2. Why are actual yields usually less than calculated theoretical yields?

3. What is the percentage yield of a reaction?

4. What is the limiting reagent? What reagent is in excess?