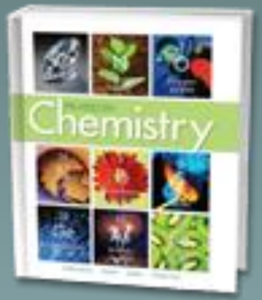
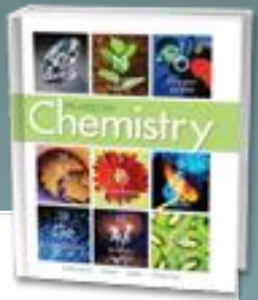


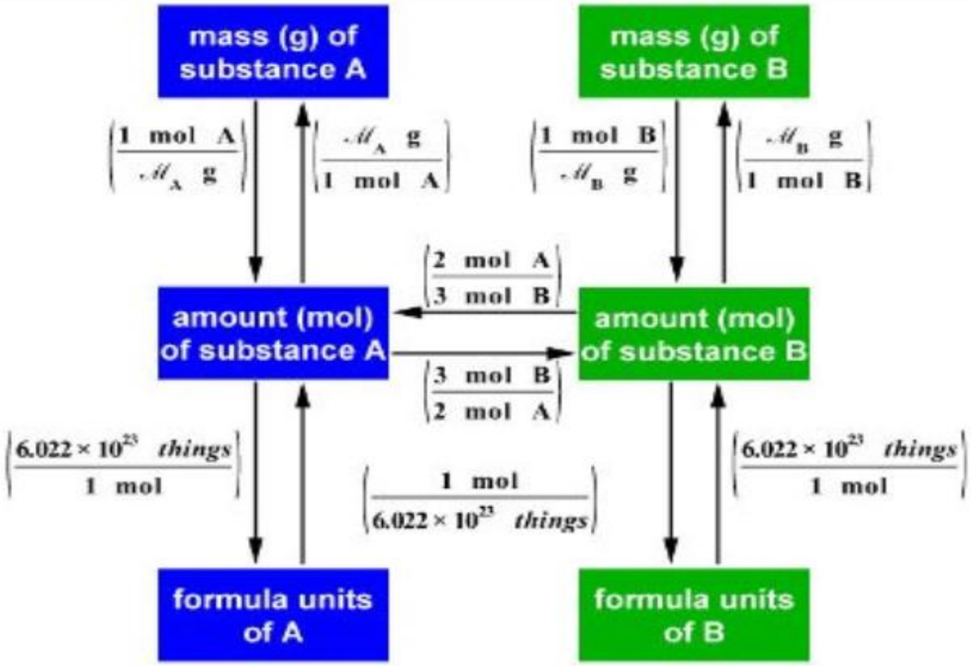
Chapter 12
Stoichiometry

The Arithmetic of Equations

Chemical Calculations

Limiting Reagent and Percent Yield





Topics:

1. Stoichiometry
2. Chemical Names and Formulas

Objectives:

1. Understand and use stoichiometry in balanced chemical equations (particularly regarding molar quantities of mass, volume, and number).
2. Explain and calculate the interconversion of reactants and products using mole ratios (coefficients).
3. Identify the limiting and excess reactants for a given reaction.
4. Use the limiting reactant to predict the theoretical yield of a reaction.
5. Calculate the percent yield of a reaction.
6. Understand Law of Definite Proportions

Solve Stoichiometric Problems

WARM-UP

Consider the combustion of acetylene (C_2H_2) in a welding torch:

$$2C_2H_2(l) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

How many grams of oxygen would be required to react completely with 859 g C_2H_2?

Solve Stoichiometric Problems

WARM-UP

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$$2C_2H_2(l) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

How many grams of oxygen would be required to react completely with 859 g C_2H_2?

Find mol C_2H_2: GMM = 26.0 g/mol

859 g x 1 mol/26.0 g = 33.0 mol

Mole ratio C_2H_2:O_2 = 2:5

Convert to mol O_2 → 33.0 mol/2 mol = X/5 mol X = 82.5 mol

Convert mol to grams GMM O_2 = 32.0 g/mol

82.5 mol x 32.0 g/mol = **2,640 g O_2**

Solve Stoichiometric Problems

How many grams of carbon dioxide would be formed if 38.9 g C_2H_2 reacted completely with oxygen?

$$2C_2H_2(l) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

Solve Stoichiometric Problems

WARM-UP

How many grams of carbon dioxide would be formed if 38.9 g C_2H_2 reacted completely with oxygen?

$$2C_2H_2(l) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

Find mol C_2H_2: GMM = 26.0 g/mol

38.9 g x 1 mol/26 g = 1.50 mol

Mole ratio C_2H_2:CO_2 = 2:4

Convert to mol CO_2 → 1.50 mol/2 mol = X/4 mol **X = 3.00 mol**

Convert mol to grams → GMM CO_2 = 44.0 g/mol

3.00 mol x 44.0 g/mol = **132 g CO_2**

Solve Stoichiometric Problems

How many **liters** of carbon dioxide would be formed if 38.9 g C_2H_2 reacted completely with oxygen?

$$2C_2H_2(l) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

Find mol C_2H_2: GMM = 26.0 g/mol

38.9 g x 1 mol/26 g = 1.50 mol

Mole ratio C_2H_2:CO_2 = 2:4

Convert to mol CO_2 → 1.50 mol/2 mol = X/4 mol **X = 3.00 mol**

Convert mol to liters → 22.4 L/mol CO_2

3.00 mol x 22.4 L/mol = **67.2 L CO_2**

Solve Stoichiometric Problems

WARM-UP

How many **molecules** of carbon dioxide would be formed if 38.9 g C_2H_2 reacted completely with oxygen?

$$2C_2H_2(l) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$$

Find mol C_2H_2: GMM = 26.0 g/mol

38.9 g x 1 mol/26 g = 1.50 mol

Mole ratio C_2H_2:CO_2 = 2:4

Convert to mol CO_2 → 1.50 mol/2 mol = X/4 mol **X = 3.00 mol**

Convert mol to molecules → 6.02 x 10^{23} molecules/mol CO_2

3.00 mol x 6.02 x 10^{23} molecules /mol = **1.8 x 10^{24} molecules CO_2**

Suppose you wanted to make banana bread according to the following recipe:

½ cup sugar	1 cup butter	1 teaspoon vanilla
1 teaspoon salt	2 bananas	2 cups flour
1 teaspoon soda	2 eggs	¼ cup milk
¼ cup walnuts	¼ cup cherries	¼ cup choc chips

The problem is you have only 1 banana. What can you do assuming you want to use the recipe above?

Suppose you wanted to make banana bread according to the following recipe:

½ cup sugar	1 cup butter	1 teaspoon vanilla
1 teaspoon salt	2 bananas	2 cups flour
1 teaspoon soda	2 eggs	¼ cup milk
¼ cup walnuts	¼ cup cherries	¼ cup choc chips

The problem is you have only 1 banana. What can you do assuming you want to use the recipe above?

Cut the recipe in half for all ingredients … since you only have ½ the bananas you need.

Quantitative Analysis deals with ACTUAL quantities versus theoretical quantities. Often you have a “limiting” issue that prevents producing what you expected.

Lesson Objectives

LESSON QUESTION

By the end of this lesson, you should be able to:

- Identify the limiting and excess reactants for a given reaction
- Use the limiting reactant to predict the theoretical yield of a reaction
- Calculate the percent yield of a reaction

Science Practice: Use mathematical procedures including dimensional analysis and significant figures when solving limiting reactant and percent yield stoichiometry problems.

Do You Have Enough?

- You are making hamburgers for a group of friends at lunch.
- Each sandwich uses 0.25 lb ground beef + 1 bun (*top & bottom*)
- You have 2.5 lb ground beef and 8 buns
- How many sandwiches can be made?

Do You Have Enough?

- You are making hamburgers for a group of friends at lunch.
- Each sandwich uses 0.25 lb ground beef + 1 bun (top & bottom)
- You have 2.5 lb ground beef and 8 buns
- How many sandwiches can be made?

- In THEORY:

  2.5 lb / 0.25 lb/burger = 10 burgers

- ACTUALLY, since you only have 8 buns, you can only make 8 burgers.

- You will therefore, have EXCESS ground beef because we run out of buns.

Limiting and Excess Reactants

Limiting Reactant:

the reactant that controls the amount of product that forms; the reactant that is consumed completely during a reaction

Excess Reactant:

any reactant that is not consumed completely during a reaction and is left over

Limiting Reactant: buns

Excess Reactant: ground beef

Limiting & excess reactant determinations must be based on molar quantities & stoichiometric relationships.

Limiting Reactants and Stoichiometry

EXAMPLE

Hydrogen and nitrogen react to produce ammonia according to the following equation:

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

If 5.00 g H_2 react with 50.0 g N_2, what is the limiting reactant?

Find Moles based on Amount Given:

Use Mole ratios:

Compare Theoretical Values:

EXAMPLE

Limiting Reactants and Stoichiometry

Hydrogen and nitrogen react to produce ammonia according to the following equation:

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

If 5.00 g H_2 react with 50.0 g N_2, what is the limiting reactant?

You cannot tell the limiting reactant based on grams, but only based on **moles (the standard) AND the mole ratio**. This is stoichiometry!

Find Moles based on Amount Given:

H_2 5.00 g x 1 mol/2.00 g = 2.50 mol

N_2 50.0 g x 1 mol/28.0 g = 1.80 mol

Use Mole ratios:

H_2 : N_2 = 3:1 theoretically

Yet, using ACTUAL mol of H_2 →

1.80/1 = X/3 X = 5.4 mol H_2

Compare Theoretical Values:

H_2 is the Limiting Reactant since 5.4 mol H_2 are needed to react with 1.80 mol N_2 and we only have 2.50 mol H_2 available.

EXAMPLE

Limiting Reactants and Stoichiometry

Hydrogen and nitrogen react to produce ammonia according to the following equation:

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Find Moles based on Amount Given:

H_2 5.00 g x 1 mol/2.00 g = 2.50 mol

N_2 50.0 g x 1 mol/28.0 g = 1.80 mol

Use Mole ratios:

$H_2 : N_2$ = 3:1 theoretically

Yet, using ACTUAL mol of H_2 →

2.50/3 = X/1 X = 0.830 mol N_2

Compare Theoretical Values:

H_2 is the Limiting Reactant since only 0.830 mol N_2 are needed to react with 2.50 mol H_2 and we have 1.80 mol N_2 available.

Limiting Reactants and Stoichiometry
done another way [same example]

Hydrogen and nitrogen react to produce ammonia according to the following equation: $3H_2(g) + N_2(g) \longrightarrow 2NH_3(g)$

If 5.00 g H_2 react with 50.0 g N_2, what is the limiting reactant?

Use the actual moles of reactants from the previous page.

H_2 5.00 g x 1 mol/2.00 g = 2.50 mol

N_2 50.0 g x 1 mol/28.0 g = 1.80 mol

Find the yield for both reactants, starting with mole ratios:

H_2 : NH_3 →

N_2 : NH_3 →

Limiting Reactants and Stoichiometry
done another way [same example]

Hydrogen and nitrogen react to produce ammonia according to the following equation: $3H_2(g) + N_2(g) \longrightarrow 2NH_3(g)$

If 5.00 g H_2 react with 50.0 g N_2, what is the limiting reactant?

Use the actual moles of reactants from the previous page.

H_2 5.00 g x 1 mol/2.00 g = 2.50 mol

N_2 50.0 g x 1 mol/28.0 g = 1.80 mol

Find the yield for both reactants, starting with mole ratios:

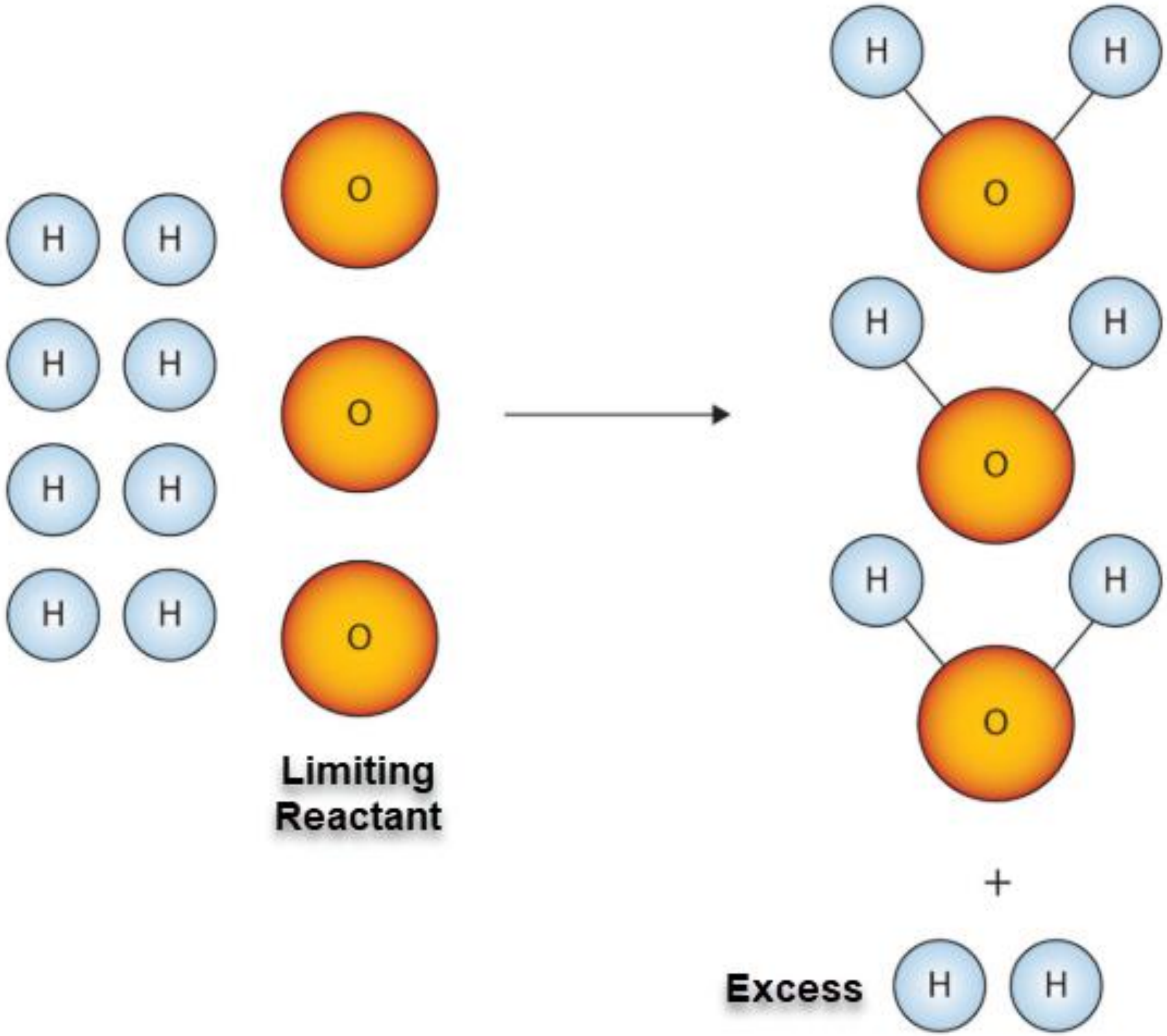
H_2 : NH_3 → 2.5 mol/3 mol → ?/2 mol = 1.67 mol NH_3

N_2 : NH_3 → 1.80 mol/1 mol → ?/2 mol = 3.60 mol NH_3

Again, we see that H_2 is the Limiting reactant because it will yield much less product, NH_3 , making N_2 the excess reactant.

EXAMPLE

Limiting Reactants and Stoichiometry done another way [same example]



The limiting reactant limits the amount of the other reactant that can combine, and the amount of product that can be formed.

The **excess reactant** is NOT completely used up in the reaction.

EXAMPLE

Copper reacts with sulfur to form copper(I) sulfide according to the following balanced equation:

$$2Cu(s) + S(s) \rightarrow Cu_2S(s)$$

What is the limiting reagent if 80.0 g Cu reacts with 25.0 g S?

Find Moles

Use Mole ratios:

Compare Theoretical Values:

EXAMPLE

Copper reacts with sulfur to form copper(I) sulfide according to the following balanced equation:

$$2Cu(s) + S(s) \rightarrow Cu_2S(s)$$

What is the limiting reagent if 80.0 g Cu reacts with 25.0 g S?

Find Moles

$$80.0\ \cancel{g\ Cu} \times \frac{1\ mol\ Cu}{63.5\ \cancel{g\ Cu}} = 1.26\ mol\ Cu$$

$$25.0\ \cancel{g\ S} \times \frac{1\ mol\ S}{32.1\ \cancel{g\ S}} = 0.779\ mol\ S$$

Use Mole ratios: Cu : S = 2:1 theoretically

Using ACTUAL mol of Cu → 1.26/2 = X/1 X = 0.630 mol S

Compare Theoretical Values:

Cu is the Limiting Reactant since only 0.630 mol S are needed to react with 1.26 mol Cu and we have 0.779 mol S available.

Mathematical Proportions can be done in different ways.

EXAMPLE

You could also solve for the actual moles of Sulfur instead.

Copper reacts with sulfur to form copper(I) sulfide according to the following balanced equation: $2Cu(s) + S(s) \rightarrow Cu_2S(s)$

What is the limiting reagent if 80.0 g Cu reacts with 25.0 g S?

Remember actual moles calculated: 1.26 mol Cu & 0.779 mol S

Use Mole ratios:

Compare Theoretical Values:

EXAMPLE

You could also solve for the actual moles of Sulfur instead.

Copper reacts with sulfur to form copper(I) sulfide according to the following balanced equation: $2Cu(s) + S(s) \rightarrow Cu_2S(s)$

What is the limiting reagent if 80.0 g Cu reacts with 25.0 g S?

Remember actual moles calculated: 1.26 mol Cu & 0.779 mol S

Use Mole ratios: S : Cu = 1:2 theoretically

Using ACTUAL mol of S → 0.779/1 = X/2 X = 1.56 mol Cu

Compare Theoretical Values:

Again we determine that Cu is the Limiting Reactant since 0.779 mol S require 1.56 mol Cu to react with, but we only have 1.26 mol Cu available.

It doesn’t matter which reactant you use. You would still identify copper as the limiting reagent.

Using the Limiting Reagent to Find the Quantity of a Product

What is the maximum number of grams of Cu_2S that can be formed when 80.0 g Cu reacts with 25.0 g S?

$$2Cu(s) + S(s) \rightarrow Cu_2S(s)$$

Use Mole ratios:

Convert Moles to grams:

Using the Limiting Reagent to Find the Quantity of a Product

What is the maximum number of grams of Cu_2S that can be formed when 80.0 g Cu reacts with 25.0 g S?

$$2Cu(s) + S(s) \rightarrow Cu_2S(s)$$

We already determined that the limiting reagent in this reaction is Cu. We calculated 1.26 mol Cu. Now, determine theoretical yield of product.

Use Mole ratios:

Cu : Cu_2S = 2:1 theoretically

ACTUAL mol of Cu → 1.26/2 = X/1 X = 0.630 mol Cu_2S

Convert Moles to grams:

0.630 mol Cu_2S x 159 g/mol = 100. g Cu_2S

$$= 1.00 \times 10^2 \text{ g } Cu_2S$$

TRY IT

Rust forms when iron, oxygen, and water react. One chemical equation for the formation of rust is:

$$2Fe + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$$

If 7.0 g of iron and 9.0 g of water are available to react, which is the limiting reagent?

Find Moles based on Amounts Given:

Use Mole ratios:

Compare Theoretical Values:

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If 7.0 g of iron and 9.0 g of water are available to react, which is the limiting reagent?

Find Moles based on Amounts Given:

Fe 7.0 g x 1 mol/55.8 g = 0.13 mol Fe

H_2O 9 g x 1 mol/18.0 g = 0.50 mol H_2O

Use Mole ratios: Fe : H_2O = 2:2 theoretically

Therefore, in theory, we need the same number of moles of both.

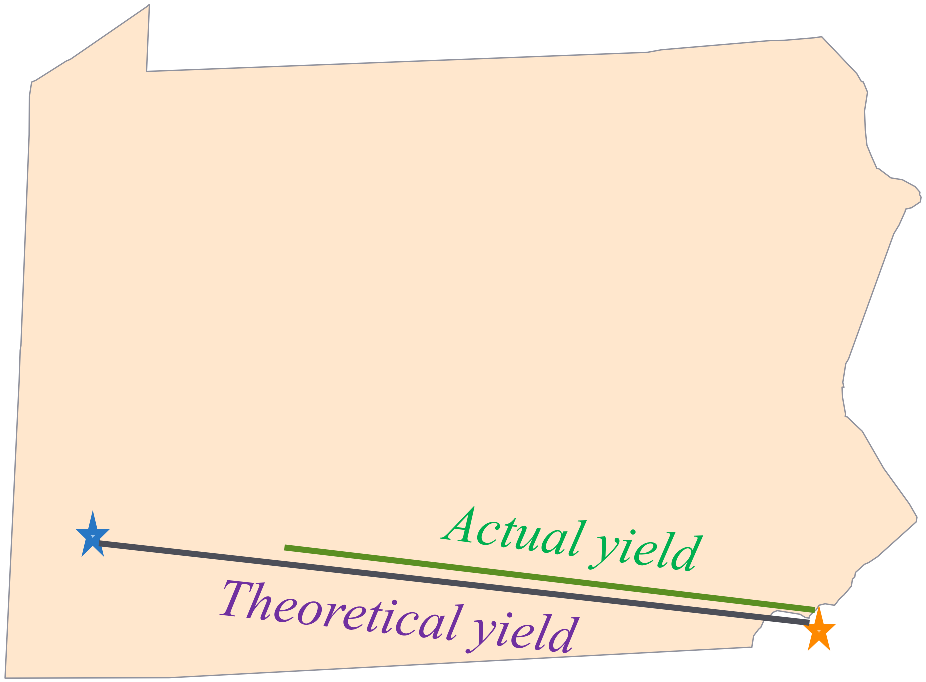
Compare Theoretical Values:

Fe is the Limiting Reactant since only 0.13 mol H_2O are needed to react with 0.13 mol Fe and we have 0.50 mol H_2O available.

Find Theoretical Yield: mol ratio of Fe : $Fe(OH)_2$ = 2:2 = 1:1

$$0.13 \text{ mol} \times 89.8 \text{ g/mol} = 12 \text{ g } Fe(OH)_2$$

How Can You Calculate the Amount of Product That Should Be Created in a Chemical Reaction?



Theoretical yield, like the theoretical distance you can drive on a tank of gas [*darker line on map to the left*], is actually a maximum possible yield.

In reality, the **actual yield** [*green line*] is less than the theoretical yield. In other words, you never drive as far on a tank as you calculate.

Percent Yield

The calculated or expected amount of product is called the **theoretical yield**.

The amount of product actually produced is called the **actual yield**.

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

Percent Yield

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The percent yield is a measure of the efficiency of a reaction carried out in the laboratory.

Reactions do not always go to completion; when a reaction is incomplete, less than the calculated amount of product is formed.

Impure reactants and competing side reactions may cause unwanted products to form.

Actual yield can be lower than the theoretical yield due to a loss of product during filtration or in transferring between containers.

EXAMPLE

Determining Percent Yield

Butane (C_4H_{10}, 58.00 g/mol) is used in lighters and camp stoves. It reacts with oxygen according to the following equation:

$$2C_4H_{10}(l) + 13O_2(g) \longrightarrow 8CO_2(g) + 10H_2O(g)$$

At a particular setting, the reaction of 100.0 g C_4H_{10} produces 285.0 g CO_2 (44.00 g/mol). What is the percent yield at this setting? Calculate theoretical yield and percent yield.

Find mol C_4H_{10}:

Mole ratio C_4H_{10} : CO_2 =

Convert mol to g CO_2 →

Calculate Percent Yield CO_2:

EXAMPLE

Determining Percent Yield

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At a particular setting, the reaction of 100.0 g C_4H_{10} produces 285.0 g CO_2 (44.00 g/mol). What is the percent yield at this setting? Calculate theoretical yield and percent yield.

Find mol C_4H_{10}: 100.0 g x 1 mol/58.00 g = 1.720 mol

Mole ratio C_4H_{10} : CO_2 = 2:8 → 1.720/2 = X/8 X = 6.880 mol CO_2

Convert mol to g CO_2 → 6.880 mol x 44.00 g/mol

= **302.7 g CO_2** **theoretical yield**

Actual Yield CO_2: 285.0 g

EXAMPLE

Determining Percent Yield

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Find mol C_4H_{10}: 100.0 g x 1 mol/58.00 g = 1.720 mol

Mole ratio C_4H_{10} : CO_2 = 2:8 → 1.720/2 = X/8 X = 6.880 mol CO_2

Convert mol to g CO_2 → 6.880 mol x 44.00 g/mol

= **302.7 g CO_2** theoretical yield

Calculate Percent Yield CO_2: *% yield = actual yield / theoretical yield x 100 %*

285.0 g / 302.7 g x 100% = **94.15% CO_2**

Importance of Percent Yield

- Comparing the percent yield for different experimental conditions helps identify the most efficient process.
- Finding percent yield helps to determine the cost of production.
- Large deviations in percent yield can indicate problems in a procedure or damage to equipment.

Theoretical Yield, Actual Yield, and Percent Yield

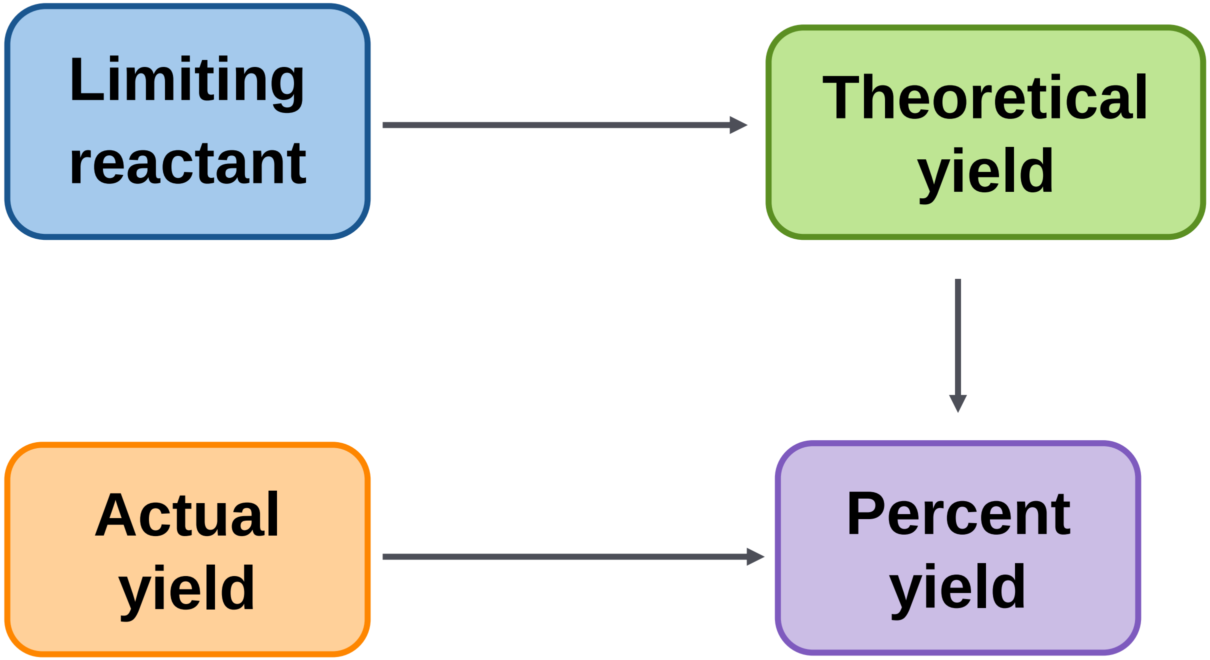
LESSON SUMMARY

- Theoretical yield is the maximum amount of product a reaction can form as determined by the limiting reactant.
- Actual yield is the observed amount of product formed in a specific reaction.
  - Actual yield is always less than theoretical yield.
- Percent yield is the ratio of actual yield to theoretical yield, expressed as a percent.

$$\%\ \text{Yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$$

Solving Problems Involving Limiting Reactants and Yield

- Identification of the **limiting reactant** allows the accurate determination of **theoretical yield**.
- **Percent yield** is a comparison of **actual yield** with theoretical yield.



Review

Calcium carbonate, found in seashells, is decomposed by heating:

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

What is the theoretical yield of CaO if 24.8 g $CaCO_3$ is heated?

Find mol $CaCO_3$ →

Mole ratio $CaCO_3$ →

Convert mol to g CaO →

Review

Calcium carbonate, found in seashells, is decomposed by heating:

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

What is the theoretical yield of CaO if 24.8 g $CaCO_3$ is heated?

Find mol $CaCO_3$ → 24.8 g x 1 mol/100.1 g = 0.250 mol

Mole ratio $CaCO_3$ → CaO = 1:1 → 0.250 mol CaO

Convert mol to g CaO → 0.250 mol x 56.1 g/mol = **13.9 g CaO**

theoretical yield

If there is an excess of a reactant, then there is more than enough of that reactant and it will not limit the yield of the reaction.

Review

Percent Yield

Using the same problem … what is the percent yield if 13.1 g CaO is actually produced when 24.8 g $CaCO_3$ is heated?

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

Review

Percent Yield

Using the same problem, what is the percent yield if 13.1 g CaO is actually produced when 24.8 g $CaCO_3$ is heated?

$$CaCO_3(s) \xrightarrow{\Delta} CaO(s) + CO_2(g)$$

actual yield = 13.1 g CaO

theoretical yield = 13.9 g CaO (from earlier problem)

$$\text{percent yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

$$\text{percent yield} = \frac{13.1 \text{ g CaO}}{13.9 \text{ g CaO}} \times 100\% = 94.2\%$$

Percent Yield

Review

Carbon tetrachloride, CCl_4, is a solvent that was once used in large amounts in dry cleaning. One reaction that produces carbon tetrachloride is: $CS_2 + 3Cl_2 \rightarrow CCl_4 + S_2Cl_2$

What is the percent yield of CCl_4 if 617 kg is produced from the reaction of 872.8 kg of Cl_2?

Find mol Cl_2

Mole ratio Cl_2 :

Convert mol to g CCl_4

Calculate Percent Yield CCl_4

Percent Yield

Review

Carbon tetrachloride, CCl_4, is a solvent that was once used in large amounts in dry cleaning. One reaction that produces carbon tetrachloride is: $CS_2 + 3Cl_2 \rightarrow CCl_4 + S_2Cl_2$

What is the percent yield of CCl_4 if 617 kg is produced from the reaction of 872.8 kg of Cl_2?

Find mol Cl_2

872.8 kg x 10^3 g/1 kg x 1 mol/71.0 g = 12,293 mol

Mole ratio Cl_2 : CCl_4 = 3:1 → 12,293/3 = 4097.7 mol CCl_4

Convert mol to g CCl_4

4097.7 mol x 153.8 g/mol x 1 kg/10^3 g = **630 kg CCl_4**

theoretical yield

Calculate Percent Yield **CCl_4** *% yield = actual yield / theoretical yield x 100 %*

617 kg / 630 kg x 100% = **97.9% CCl_4**

Identify Limiting and Theoretical Yield

Acetylene torches are used for welding, but the thermite reaction can be useful in situations in which acetylene torches are inappropriate, such as welding underwater. The thermite reaction is described by the equation: $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

A welder has 1.873×10^2 g Fe_2O_3 and 94.51 g Al in his welding kit. **Which reactant will he run out of first? What is the theoretical yield and percent yield of aluminum oxide?**

Identify Limiting and Excess Reactants

TRY IT

Acetylene torches are used for welding, but the thermite reaction can be useful in situations in which acetylene torches are inappropriate, such as welding underwater. The thermite reaction is described by the equation: $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

A welder has 1.873×10^2 g Fe_2O_3 and 94.51 g Al in his welding kit. **Which reactant will he run out of first? What is the theoretical yield and percent yield of aluminum oxide?**

Find Moles based on Amount Given:

Fe_2O_3 1.873×10^2 g x 1 mol/159.6 g = 1.174 mol Fe_2O_3

Al 94.51 g x 1 mol/27.00 g = 3.500 mol Al

Use Mole ratios: Fe_2O_3 : Al = 1:2 theoretically

Yet, using ACTUAL mol of Fe_2O_3 → 1.174/1 = X/2 X = 2.347 mol Al

Compare Theoretical Values:

Fe_2O_3 is the Limiting Reactant since only 2.347 mol Al are needed to react with 1.174 mol Fe_2O_3 and we have 3.500 mol Al available.

Determine theoretical yield and percent yield.

TRY IT

Identify Limiting and Excess Reactants

Acetylene torches are used for welding, but the thermite reaction can be useful in situations in which acetylene torches are inappropriate, such as welding underwater. The thermite reaction is described by the equation:
$Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

A welder has 1.873×10^2 g Fe_2O_3 and 94.51 g Al in his welding kit. **Which reactant will he run out of first?** **What is the theoretical yield of aluminum oxide?**

Find Moles based on Amount Given:

Fe_2O_3 1.873×10^2 g x 1 mol/159.6 g = **1.174 mol Fe_2O_3**
Al 94.51 g x 1 mol/27.00 g = 3.500 mol Al

Use Mole ratios: Fe_2O_3 : Al = 1:2 theoretically
Yet, using ACTUAL mol of Fe_2O_3 → 1.174/1 = X/2 X = 2.347 mol Al

Compare Theoretical Values:
Fe_2O_3 is the Limiting Reactant since only 2.347 mol Al are needed to react with 1.174 mol Fe_2O_3 and we have 3.500 mol Al available.

Theoretical Yield of aluminum oxide

1:1 mole ratio of Fe_2O_3 : Al_2O_3

1.174 mol x 102.0 g/mol = **119.7 g Al_2O_3**

TRY IT Identify Limiting and Excess Reactants

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A welder has 1.873×10^2 g Fe_2O_3 and 94.51 g Al in his welding kit. **Which reactant will he run out of first? What is the theoretical yield of aluminum oxide?**

Find Moles based on Amount Given:

Fe_2O_3 1.873×10^2 g x 1 mol/159.6 g = **1.174 mol Fe_2O_3**
Al 94.51 g x 1 mol/27.00 g = 3.500 mol Al

Use Mole ratios: Fe_2O_3 : Al = 1:2 theoretically
Yet, using ACTUAL mol of Fe_2O_3 → 1.174/1 = X/2 X = 2.347 mol Al

Compare Theoretical Values:
Fe_2O_3 is the Limiting Reactant since only 2.347 mol Al are needed to react with 1.174 mol Fe_2O_3 and we have 3.500 mol Al available.

Theoretical Yield of aluminum oxide

1:1 mole ratio of Fe_2O_3 : Al_2O_3 . 1.174 mol x 102.0 g/mol = **119.7 g Al_2O_3**

Percent Yield of aluminum oxide if actual yield = 105.8 g

% yield = actual yield / theoretical yield x 100 %

105.8 g / 119.7 g x 100% = **88 %**

Relative atomic masses are based on ^{12}C = 12.00000

KEY

Atomic Mass	12.0111
Selected Oxidation States	−4, +2, +4
Symbol	C
Atomic Number	6
Electron Configuration	$1s^2 2s^2 2p^2$

New Designation / Former Designation (prior to 1984 IUPAC decision)

s-block · *d*-block · Transition Elements

Period	1 IA (*s*-block)	2 IIA (*s*-block)	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	
1	1.00794 +1 −1 **H** 1 $1s^1$										
2	6.941 +1 **Li** 3 $1s^2 2s^1$	9.01218 +2 **Be** 4 $1s^2 2s^2$									
3	22.98977 +1 **Na** 11 $[Ne]3s^1$	24.305 +2 **Mg** 12 $[Ne]3s^2$									
4	39.0983 +1 **K** 19 $[Ar]4s^1$	40.08 +2 **Ca** 20 $[Ar]4s^2$	44.9559 +3 **Sc** 21 $[Ar]3d^1 4s^2$	47.88 +2 +3 +4 **Ti** 22 $[Ar]3d^2 4s^2$	50.9415 +2 +3 +4 +5 **V** 23 $[Ar]3d^3 4s^2$	51.996 +2 +3 +6 **Cr** 24 $[Ar]3d^5 4s^1$	54.9380 +2 +3 +4 +7 **Mn** 25 $[Ar]3d^5 4s^2$	55.847 +2 +3 **Fe** 26 $[Ar]3d^6 4s^2$	58.9332 +2 +3 **Co** 27 $[Ar]3d^7 4s^2$	58.69 +2 +3 **Ni** 28 $[Ar]3d^8 4s^2$	63.546 29 [Ar]3d
5	85.4678 +1 **Rb** 37 $[Kr]5s^1$	87.62 +2 **Sr** 38 $[Kr]5s^2$	88.9059 +3 **Y** 39 $[Kr]4d^1 5s^2$	91.224 +4 **Zr** 40 $[Kr]4d^2 5s^2$	92.9064 +3 +5 **Nb** 41 $[Kr]4d^4 5s^1$	95.94 +3 +6 **Mo** 42 $[Kr]4d^5 5s^1$	(98) +4 +6 +7 **Tc** 43 $[Kr]4d^6 5s^1$	101.07 +3 **Ru** 44 $[Kr]4d^7 5s^1$	102.906 +3 **Rh** 45 $[Kr]4d^8 5s^1$	106.42 +2 +4 **Pd** 46 $[Kr]4d^{10} 5s^0$	107.86 47 [Kr]4d
6	132.905 +1 **Cs** 55 $[Xe]6s^1$	137.33 +2 **Ba** 56 $[Xe]6s^2$	**La-Lu** 57 71	178.49 +4 **Hf** 72 $[Xe]4f^{14}5d^2 6s^2$	180.948 +5 **Ta** 73 $[Xe]4f^{14}5d^3 6s^2$	183.85 +6 **W** 74 $[Xe]4f^{14}5d^4 6s^2$	186.207 +4 +6 +7 **Re** 75 $[Xe]4f^{14}5d^5 6s^2$	190.2 +3 +4 **Os** 76 $[Xe]4f^{14}5d^6 6s^2$	192.22 +3 +4 **Ir** 77 $[Xe]4f^{14}5d^7 6s^2$	195.08 +2 +4 **Pt** 78 $[Xe]4f^{14}5d^9 6s^1$	196.96 79 [Xe]4f
7	(223) +1 **Fr** 87 $[Rn]7s^1$	226.025 +2 **Ra** 88 $[Rn]7s^2$	**Ac-Lr** 89 103	(261) **Unq*** 104	(262) **Unp** 105	(263) **Unh** 106	(262) **Uns** 107	**Uno** 108	**Une** 109		* The sys 103 wil

nasses are
2.00000

lation States

s-block

p-block

GROUP

10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 O
								4.00260 0 **He** 2 $1s^2$
			10.81 +3 **B** 5 $1s^2 2s^2 2p^1$	12.0111 −4 +2 +4 **C** 6 $1s^2 2s^2 2p^2$	14.0067 −3 −2 −1 +1 +2 +3 +4 +5 **N** 7 $1s^2 2s^2 2p^3$	15.9994 −2 **O** 8 $1s^2 2s^2 2p^4$	18.998403 −1 **F** 9 $1s^2 2s^2 2p^5$	20.179 0 **Ne** 10 $1s^2 2s^2 2p^6$
			26.98154 +3 **Al** 13 [Ne]$3s^2 3p^1$	28.0855 −4 +2 +4 **Si** 14 [Ne]$3s^2 3p^2$	30.97376 −3 +3 +5 **P** 15 [Ne]$3s^2 3p^3$	32.06 −2 +4 +6 **S** 16 [Ne]$3s^2 3p^4$	35.453 −1 +1 +3 +5 +7 **Cl** 17 [Ne]$3s^2 3p^5$	39.948 0 **Ar** 18 [Ne]$3s^2 3p^6$
58.69 +2 +3 **Ni** 28 [Ar]$3d^8 4s^2$	63.546 +1 +2 **Cu** 29 [Ar]$3d^{10} 4s^1$	65.39 +2 **Zn** 30 [Ar]$3d^{10} 4s^2$	69.72 +3 **Ga** 31 [Ar]$3d^{10} 4s^2 4p^1$	72.59 −4 +2 +4 **Ge** 32 [Ar]$3d^{10} 4s^2 4p^2$	74.9216 −3 +3 +5 **As** 33 [Ar]$3d^{10} 4s^2 4p^3$	78.96 −2 +4 +6 **Se** 34 [Ar]$3d^{10} 4s^2 4p^4$	79.904 −1 +1 +5 **Br** 35 [Ar]$3d^{10} 4s^2 4p^5$	83.80 0 +2 **Kr** 36 [Ar]$3d^{10} 4s^2 4p^6$
106.42 +2 +4 **Pd** 46 [Kr]$4d^{10} 5s^0$	107.868 +1 **Ag** 47 [Kr]$4d^{10} 5s^1$	112.41 +2 **Cd** 48 [Kr]$4d^{10} 5s^2$	114.82 +3 **In** 49 [Kr]$4d^{10} 5s^2 5p^1$	118.71 +2 +4 **Sn** 50 [Kr]$4d^{10} 5s^2 5p^2$	121.75 −3 +3 +5 **Sb** 51 [Kr]$4d^{10} 5s^2 5p^3$	127.60 −2 +4 +6 **Te** 52 [Kr]$4d^{10} 5s^2 5p^4$	126.905 −1 +1 +5 +7 **I** 53 [Kr]$4d^{10} 5s^2 5p^5$	131.29 0 +2 +4 +6 **Xe** 54 [Kr]$4d^{10} 5s^2 5p^6$
195.08 +2 +4 **Pt** 78 [Xe]$4f^{14} 5d^9 6s^1$	196.967 +1 +3 **Au** 79 [Xe]$4f^{14} 5d^{10} 6s^1$	200.59 +1 +2 **Hg** 80 [Xe]$4f^{14} 5d^{10} 6s^2$	204.383 +1 +3 **Tl** 81 [Xe]$4f^{14} 5d^{10} 6s^2 6p^1$	207.2 +2 +4 **Pb** 82 [Xe]$4f^{14} 5d^{10} 6s^2 6p^2$	208.980 +3 +5 **Bi** 83 [Xe]$4f^{14} 5d^{10} 6s^2 6p^3$	(209) +2 +4 **Po** 84 [Xe]$4f^{14} 5d^{10} 6s^2 6p^4$	(210) **At** 85 [Xe]$4f^{14} 5d^{10} 6s^2 6p^5$	(222) 0 **Rn** 86 [Xe]$4f^{14} 5d^{10} 6s^2 6p^6$

Polyatomic Ions

Name	Formula	Name	Formula
perPhosphate	$(PO_5)^{-3}$	perCarbonate	$(CO_4)^{-2}$
Phosphate	$(PO_4)^{-3}$	**Carbonate**	$(CO_3)^{-2}$
Phosphite	$(PO_3)^{-3}$	Carbonite	$(CO_2)^{-2}$
hypoPhosphite	$(PO_2)^{-3}$	hypocarbonite	$(CO)^{-2}$
perChlorate	$(ClO_4)^{-1}$	perNitrate	$(NO_4)^{-}$
Chlorate	$(ClO_3)^{-1}$	**Nitrate**	$(NO_3)^{-}$
Chlorite	$(ClO_2)^{-1}$	Nitrite	$(NO_2)^{-}$
hypoChlorite	$(ClO)^{-1}$	Hyponitrite	$(NO)^{-}$
perSulfate	$(SO_5)^{-2}$	perChromate	$(CrO_5)^{-2}$
Sulfate	$(SO_4)^{-2}$	**Chromate**	$(CrO_4)^{-2}$
Sulfite	$(SO_3)^{-2}$	Chromite	$(CrO_3)^{-2}$
hyposulfite	$(SO_2^{-2}$	Hypochromite	$(CrO_2)^{-2}$
Acetate	$(C_2H_3O_2)^{-1}$	**Cyanide**	$(CN)^{-1}$
Hydroxide	$(OH)^{-1}$	**Manganate**	$(MnO_4)^{-2}$

Ammonium
$(NH_4)^{+1}$

IONIZATION ENERGIES AND ELECTRONEGATIVITIES

First Ionization Energy (kcal/mol of atoms) — upper number in each box

Electronegativity* — lower number in each box

1	2	13	14	15	16	17	18
H 313 / 2.2							He 567
Li 125 / 1.0	Be 215 / 1.5	B 191 / 2.0	C 260 / 2.6	N 336 / 3.1	O 314 / 3.5	F 402 / 4.0	Ne 497
Na 119 / 0.9	Mg 176 / 1.2	Al 138 / 1.5	Si 188 / 1.9	P 242 / 2.2	S 239 / 2.6	Cl 300 / 3.2	Ar 363
K 100 / 0.8	Ca 141 / 1.0	Ga 138 / 1.6	Ge 182 / 1.9	As 226 / 2.0	Se 225 / 2.5	Br 273 / 2.9	Kr 323
Rb 96 / 0.8	Sr 131 / 1.0	In 133 / 1.7	Sn 169 / 1.8	Sb 199 / 2.1	Te 208 / 2.3	I 241 / 2.7	Xe 280
Cs 90 / 0.7	Ba 120 / 0.9	Tl 141 / 1.8	Pb 171 / 1.8	Bi 168 / 1.9	Po 194 / 2.0	At / 2.2	Rn 248
Fr / 0.7	Ra 122 / 0.9						

* Arbitrary scale based on fluorine = 4.0