Unit 6 – Stoichiometry

Progress Tracker

Test Date:

Webassign Due	*Score*

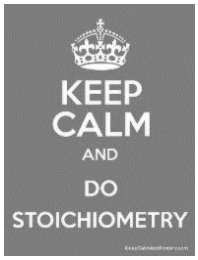
Packet Progress Checks	

Test Readiness Checks:

- ☐ My webassign scores indicate I am ready for the test.
- ☐ I went to ASP for Webassign help when needed.
- ☐ I have completed the unit review AND checked my answers.
- ☐ I am aware that I cannot retake the test unless my webaassign and packet progress checks are all above 80%.

Learning Objectives

6.1 Stoichiometry



6.1 Stoichiometry

- Understand the goal of doing stoichiometric calculations.
- Understand the importance of a **balanced chemical equation** in determining the **mole ratios** to be used in calculations.
- Calculate the **theoretical yield** of product that could be produced by a chemical reaction.
- Calculate the amount of reactants needed to make a certain amount of product.
- Determine the **limiting reagent** in a reaction quantitatively.
- Determine the amount of **excess reagent** that will remain in the flask at the end of a reaction.
- Demonstrate an understanding of limiting reagents (and stoichiometry) by drawing a **particle diagram** that accurately represents the chemical species that remain in a flask at the end of a reaction.
- Determine the **percent yield** of a reaction:

$$\%\ yield = \left(\frac{actual\ yield}{theoretical\ yield}\right) x\ 100$$

- Be able to conduct stoichiometric calculations when measurements are provided in grams or moles. Also be able to work with **solutions** (M and mL)
- Be able to use and describe simple gravimetric lab techniques: **decanting**, **filtration**, **oven drying**, **tare weighting filter paper**, etc.
- Be able to use **lab data** (as opposed to problem provided data to do stoichiometric calculations.

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Balanced Equations and Stoichiometry

Key Skill: Interpreting a Balanced Chemical Equation

In a chemical equation, the **coefficients** tell us how many molecules are reacting.

Example:

1H_2 + **1**Cl_2 → **2** HCl

We can represent what is happening with a diagram:

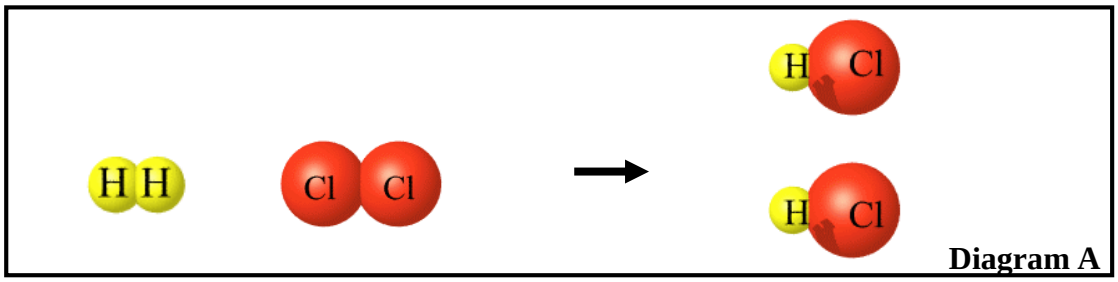
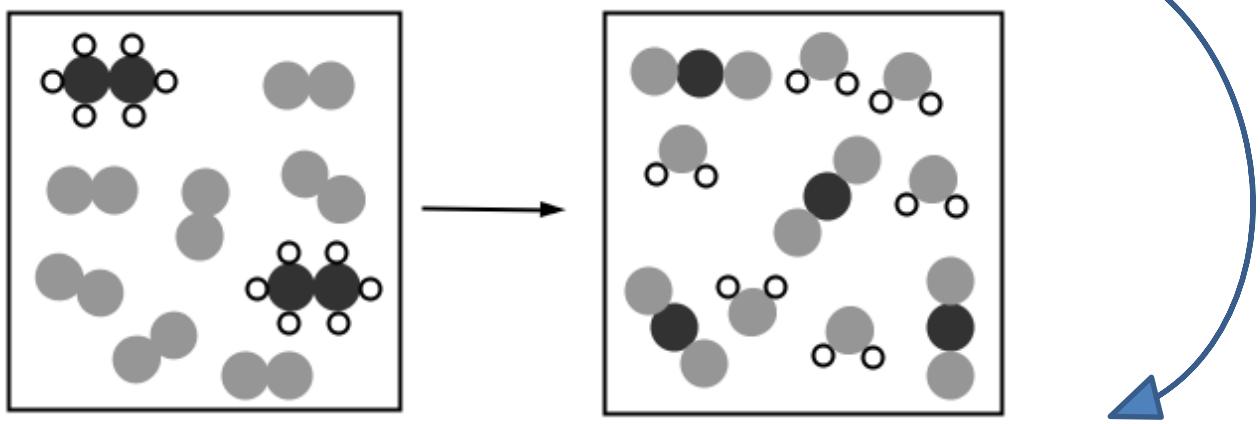


Diagram A

1. Given the particle diagram below, predict the balanced equation.



___ Black-White molecule + ___ Gray-Gray molecule → ___Gray-White Molecule + __ Gray-Black molecule

2. Balance the equation shown below.

$$____N_2 \quad + \quad __ H_2 \quad \rightarrow \quad ___ NH_3$$

The diagram below (Diagram C) shows the reactants as they exist before the reaction begins. Draw how the container will look after the reaction. (Consider how the molecules will look and how many molecules there will be.)

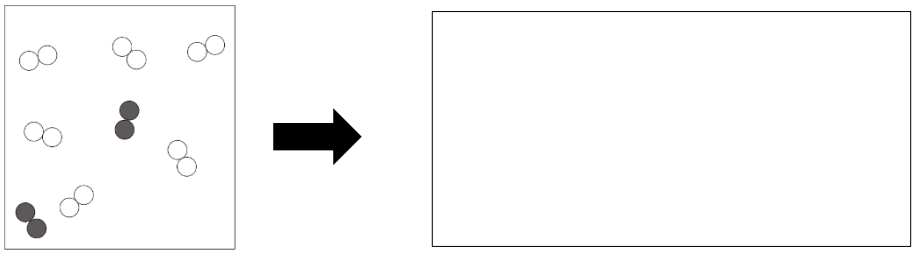


Diagram C

Before Reaction After Reaction

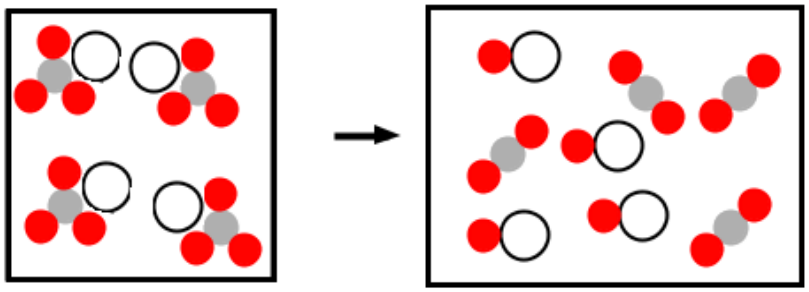


Diagram D

Before Reaction After Reaction

3. The diagram above (Diagram D) represents the following reaction.

$$CaCO_3 \rightarrow CO_2 + CaO$$

(a) Label the atoms in the diagram with the correct atom symbol. (Is the biggest atom Ca or C or O? Label the other atoms as well.)

(b) *Based on the drawing*, what must be the coefficients for each chemical species? Record the coefficients in this equation: $__CaCO_3 \rightarrow __ CO_2 + __ CaO$

(c) Balance the equation in the traditional manner below. $__CaCO_3 \rightarrow __ CO_2 + __ CaO$

(d) Does your answer in part (b) agree with your answer in part (c). Explain any differences._____

_____

_____

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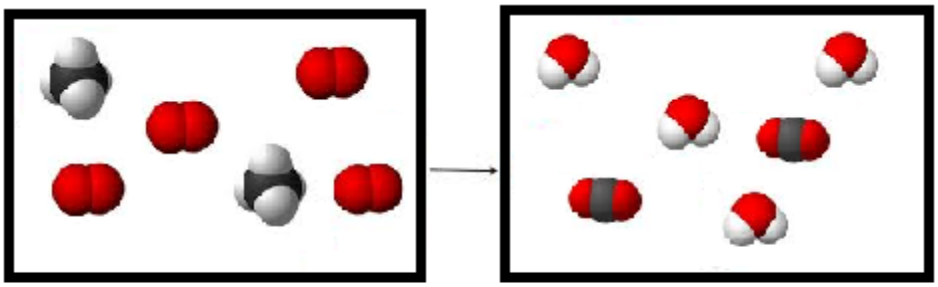
4. Balance the following reaction:

____ O_2 + ____ CH_4 → ____ CO_2 + ____ H_2O

Based on your balanced equation and the diagram below, match each shape in the drawing with its formula. (i.e. – which shape represents CO_2?)



Before the Reaction After the Reaction

Diagram E

_____

_____

_____

_____

Both products have similar structures. Describe the evidence that you used to identify the compounds on the product side of the reaction.

_____
_____
_____
_____
_____
_____
_____
_____

Stoichiometry Vocabulary

Key vocabulary for stoichiometry:

Used Needed Required Produced Consumed Formed

Example:

2 sticks of butter were _____ to make 1 dozen cookies.

$$C_3H_8 + 5\ O_2 \rightarrow 3\ CO_2 + 4\ H_2O$$

1. How many moles of O_2 are _____ to completely react with 1 mole of C_3H_8?

2. How many moles of CO_2 _____ when 5 moles of O_2 react?

3. How many moles of H_2O _____ when 1 mole of C_3H_8 react?

4. How many moles of C_3H_8 are _____ to produce 8 moles of H_2O?

Practice:

$$2\ Mg + O_2 \rightarrow 2\ MgO$$

1. How many moles of O_2 are _____ to completely react with 6 moles of Mg? Answer: _____

2. How many moles of MgO _____ when 3 moles of O_2 react? Answer: _____

3. How many moles of MgO _____ when 8 moles of Mg react? Answer: _____

4. How many moles of O_2 are _____ to produce 20 moles of MgO? Answer: _____

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Moles and Equations Practice

1) Answer the following questions for this equation. Be sure to balance the equation first

___ H_2 + ___O_2 ---> ___ H_2O

a) Suppose you had 20 moles of H_2 on hand, how many

moles of H_2O could you make? _____

b) If you wanted to react 8 moles of H_2, how many moles of O_2 would you need?_____

c) Suppose you had 20 moles of O_2, how many moles of H_2O

could you make? _____

d) If you needed to make 100 moles of H_2O, how many moles of O_2 would be required?

2) Use this equation: _KBr + ___I_2 ---> __KI + ____Br_2 for the following problems.

a) If you reacted 2.8 moles of KBr how many moles of Br_2 would you make? _____

b) If 1.5 moles of I_2 were reacted, how many moles of KBr would be required? _____

c) If 3.00 moles of I_2 were used, how many moles of KI would be made? _____

d) If 0.600 moles of KI were produced, how many moles of KBr are required? _____

Before and After Diagrams

Before and After Diagrams are a useful way to organize your thinking about how a reaction proceeds.

Example 1: How many moles of HCl would be created from the reaction of 6.2 moles of $TiCl_4$?

$$TiCl_4 + 2H_2O \longrightarrow 4HCl + TiO_2$$

Before	
△	
After	

Example 2: How many moles of H_2O would be needed to make 0.8 moles of TiO_2?

$$TiCl_4 + 2H_2O \longrightarrow 4HCl + TiO_2$$

Before	
△	
After	

Reflective Questions: Why is the change value for reactants always negative?

_____

_____

What **units** must always be used in a *Before and After Diagram*? _____

Practice 1:

- C_2H_6 is combusted in the presence of oxygen. Draw the balanced reaction that would occur.

- If you reacted 0.300 moles of O_2 with excess C_2H_6, how many moles of CO_2 would be produced? Draw a Before and After Diagram as an explanation of your work.

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Practice 2:

- $Ca(ClO_3)_2$ is decomposed with strong heating. Draw the balanced reaction that occurs.

- If you needed to produce 18 moles of oxygen gas, how many moles of $Ca(ClO_3)_2$ would you need to decompose?

As the stoichiometry becomes more complex, we will find it useful to use variables for the change value.

Variables Example 1:

- C_3H_8 is combusted in the presence of oxygen. Draw the balanced reaction that would occur.

Before	
△	
After	

- If you reacted 0.300 moles of O_2 with excess C_3H_8, how many moles of CO_2 would be produced?

Variables Example 2:

- Aluminum sulfate is reacted with sodium metal. Draw the balanced reaction that would occur.

Before	
△	
After	

- How many moles of Na would be required to make 14.17 moles of Aluminum metal?

Mole Stoichiometry Practice

Use *Before and After Diagrams* to answer each of the questions below. Remember to show what value "x" represents. Put units on your final answer.

1. Balance the following equation

$$CaH_2 + H_2O \rightarrow Ca(OH)_2 + H_2$$

2. If you started with 2.50 moles of CaH_2, how many moles of H_2 would be produced? (The reaction is redrawn to speed up the creation of your Before and After diagram.)

$$CaH_2 + H_2O \rightarrow Ca(OH)_2 + H_2$$

3. If you wanted to react 0.0400 moles of CaH_2, how many moles of water would you need?

$$CaH_2 + H_2O \qquad Ca(OH)_2 + H_2$$

4. 0.00215 moles of NaN_3 is decomposed as shown below. How many moles of nitrogen gas would result?

$$NaN_3 \rightarrow Na + N_2$$

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5. You have 0.65 moles of ammonia (NH3) in your chemical stockroom. When you conduct the reaction shown below, how many moles of the oxygen in the room would end up being used?

$$4\ NH_3\ (g) + 5\ O_2\ (g) \longrightarrow 4\ NO\ (g) + 6\ H_2O\ (l)$$

6. If you wanted to react 5.00 grams of iron (Fe) in the reaction shown below, how many moles of iron sulfide would result. (*Reminder: what type of units do we normally use in a Before and After Diagram?*)

$$8\ Fe + S_8 \longrightarrow 8\ FeS$$

Gram Stoichiometry Practice

Be sure to show your work using *Before and After Diagrams*. Also show any unit conversions that were required. You may need to draw a balanced equation before you start.

1. (a) Draw a balanced equation for the synthesis reaction that occurs between hydrogen gas and oxygen gas.

   (b) Calculate the number of grams of water that would be produced when 60 grams of oxygen is reacted with excess hydrogen.

2. Calculate the number of grams of Cu metal that would react with O_2 to make 20 grams of CuO. (You will need a balanced equation.)

3. How many grams of P would be produced when the following reaction is conducted at high temperature? (Balance the equation.)

   $$Ca_3(PO_4)_2 + SiO_2 + C \longrightarrow CaSiO_3 + P + CO$$

   How many grams of $CaSiO_3$ would be formed from 100 grams of carbon?

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4. Magnesium burns in air (O_2) to form magnesium oxide. If 2 grams of magnesium were burned, how many grams of magnesium oxide would be formed?

5. Ethane gas (C_2H_6) reacts with oxygen to form carbon dioxide and water. Exchange papers with a neighbor that is done with the previous work and write a question for your neighbor to solve based on this reaction.

   _____
   _____
   _____
   _____

6. Now exchange papers back and solve the problem.

Chemistry Can Make Us Rich Lab

Name: _____

Goals:

- To turn copper into silver!
- To practice using stoichiometry to calculate how much silver we should get.
- To determine the correct chemical equation for the reaction.

Safety: $AgNO_3$ is toxic if you eat it and will stain your hands. Wash your hands thoroughly after the lab. Wear Goggles at all times!

Pre-Lab: This reaction is a single displacement reaction. $AgNO_3$ is reacting with Cu wire. You will need to predict the products. Draw the complete reaction twice. Once showing the reaction if we assume Cu is +1 charge, and a second time if it is +2. Balance both reactions.

Reaction 1:

Reaction 2:

Part 1:

- Make 40 mL of a 0.07M $AgNO_3$. Put the final solution in the smallest beaker that you have.
- Take (approximately) 8 inches of Cu wire. Coil it over a pencil. Weigh the Cu: _____g
- Hang the Cu wire from a pencil so that most of it is in the $AgNO_3$ solution. Return to your seat so that we can work on some things while letting the reaction work its magic.

Part 2: Procedure to get your silver clean, dry, and ready to weigh:

- Reminder: Careful with the $AgNO_3$!!!
- Decant (pour carefully) the solution into one of the waste containers. Be careful to not let any of the Ag fall out.

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- Use a water spray bottle to rinse the Cu wire. Do this so that the Ag metal falls with the water into the beaker.
- Decant the liquid into the waste bin being careful not to lose any Ag.
- Repeat this process again.
- Dip your Cu wire in acetone, let it air dry for 3 minutes, then weigh it on the same balance that you used yesterday. _____g.
- Place your Ag beaker on the tray for it to be dried overnight.

Now for the calculations:

- Not all of the Cu wire completed the reaction. How can we determine the mass of Cu that actually did the reaction? (Look at the only two values that you have measure thus far). Show your work here and put your answer in appropriate spot in the box below:

How did you determine the amount of Cu that reacted?:

Now that you know how much copper reacted, draw a before and after diagram and determine how much silver you should get if reaction 1 is the correct reaction:
Reaction 1:

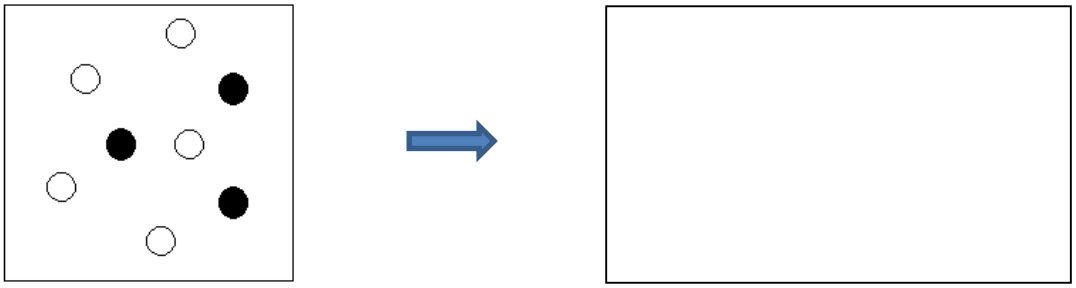
Draw a before and after diagram and determine how much silver you should get if reaction 2 is the correct reaction:
Reaction 2:

- Remove your dried silver from the oven and mass it. Which reaction was better at predicting the amount of Ag recovered? Explain how you know. Provide evidence in your explanation.

Understanding Limiting Reagents

1. The diagram below shows the amount of hydrogen and oxygen BEFORE the reaction. What would the diagram look like AFTER the reaction is complete? Which chemical is not completely used up?

$$Fe + S \rightarrow FeS$$



Limiting reagent:

_____

_____

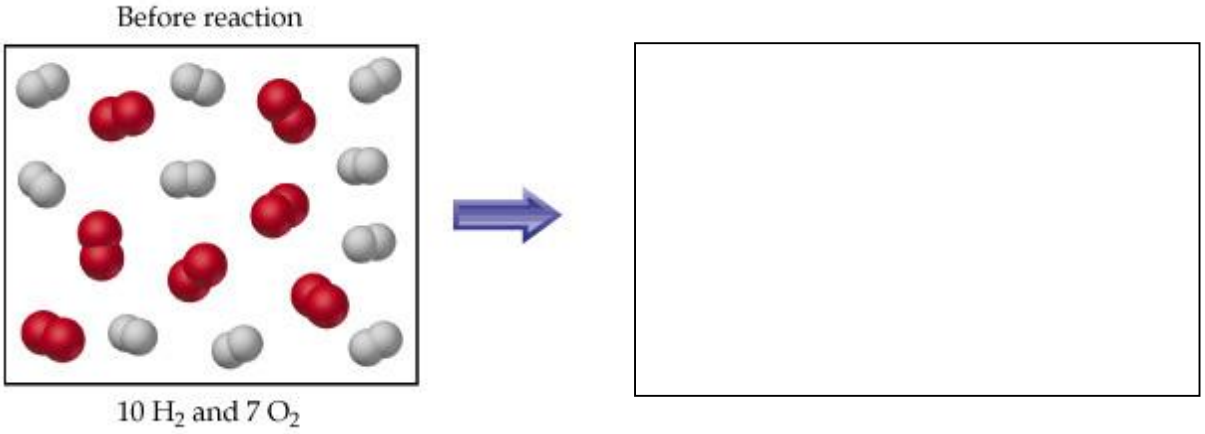
Excess reagent:

_____

_____

2. A reaction of H_2 and O_2 occurs according to this reaction:

$$H_2 + O_2 \rightarrow H_2O$$



What is the limiting reagent? _____

How much of the excess reagent remains in the end? _____

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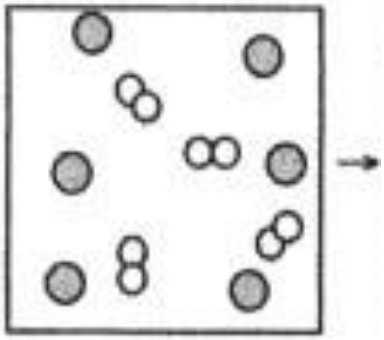
3. "Build" your molecules to determine the limiting reagent in this reaction:

$$C + Br_2 \rightarrow CBr_4$$

Label the dark and light color circles with the atom they represent.

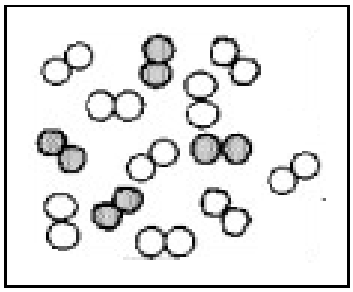


What is the limiting reagent? _____
How much of the excess reagent remains in the end? _____

4. "Build" your molecules to determine the limiting reagent in this reaction:

$$N_2 + Cl_2 \rightarrow NCl_3$$

The dark colored spheres are nitrogen and the light colored spheres are chlorine.



What is the limiting reagent? _____
How much of the excess reagent remains in the end? _____

Limiting Reagents in Stoich

Question: How do we determine the chemical (or reagent) that will be used up first?

Example 1: If 6 moles of $TiCl_4$ reacts with 8 moles of H_2O, which chemical is the limiting reagent?

$$TiCl_4 + 2H_2O \longrightarrow 4HCl + TiO_2$$

Before				
△				
After				

Example 2: If 0.60 moles of NaCl reacts with 0.60 moles of O_2, what is the limiting reagent?

$$2\ NaCl + 3\ O_2 \longrightarrow 2\ NaClO_3$$

Before			
△			
After			

How many grams of moles of $NaClO_3$ would be made in the reaction?

Practice 1:

- C_2H_4 is combusted in the presence of oxygen. Draw the balanced reaction that would occur.

- If you reacted 2 moles of O_2 with 1 mole of C_2H_4, what is the limiting reagent?

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Practice 2:

- Aluminum sulfate is reacted with sodium metal. Draw the balanced reaction that would occur.

- If 0.50 moles of aluminum sulfate is reacted with 1.20moles of Na metal, what is the limiting reagent?

- Determine the number of moles of both products that would be made in the reaction.

Limiting Reagent Practice (moles)

In each case, **identify the limiting reagent**. (**Show your work**!)

1. $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

(a) 2.00 moles of C_2H_4 are reacted with excess O_2.

(b) 3.00 moles of C_2H_4 are reacted with 5.00 moles of O_2 (Use a B&A diagram)

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

(c) 1.45 moles of C_2H_4 are reacted with 5.00 moles of O_2

$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

2. $Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$

(a) 27 moles of Zn are reacted with excess HCl.

$Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$

(b) 1.49 moles of Zn are reacted with 2.81moles of HCl.

$Zn + 2\ HCl \rightarrow ZnCl_2 + H_2$

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3. $4\ Al + 2\ O_2 \rightarrow 2\ Al_2O_3$

(a) 0.8 moles of Mg are reacted with excess O_2.

(b) 0.72 moles of Mg are reacted with 0.22 moles of O_2.

$4\ Al + 2\ O_2 \rightarrow 2\ Al_2O_3$

(c) 2.61 **grams** of Mg are reacted with 1.26 **grams** of O_2.

Limiting Reagents (Grams)

1. Given the following reaction: (hint: balance the equation first)

$$C_3H_8 + O_2 \text{ -------> } CO_2 + H_2O$$

If you start with 14.8 g of C_3H_8 and 3.44 g of O_2,

a) determine the limiting reagent. (Record your answer here in sentence after you do the work above.)
The Limiting Reagent is _____ . My evidence for this answer is…
_____
_____

b) determine the number of grams of carbon dioxide produced. (Your B&A table provides most of the evidence. Include any extra calculations needed here:)

c) determine the number of grams of H_2O produced. (Your B&A table provides most of the evidence. Include any extra calculations needed here:)

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2. Given the following equation:

$$Al_2(SO_3)_3 + 6\ NaOH \text{ ------> } 3\ Na_2SO_3 + 2\ Al(OH)_3$$

a) If 10.0 g of $Al_2(SO_3)_3$ is reacted with 10.0 g of NaOH, determine the limiting reagent. The Limiting Reagent is _____ . My evidence for this answer is…

_____

_____

b) Determine the number of g of $Al(OH)_3$ produced

c) Determine the number of grams of Na_2SO_3 produced

3. Given the following equation: (hint: balance the equation first)

Al_2O_3 + Fe ------> Fe_3O_4 + Al

a) If 25.4 g of Al_2O_3 is reacted with 10.2 g of Fe, determine the limiting reagent

b) Determine the number of g of Al produced

c) Determine the number of grams of Fe_3O_4 produced

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12
C
Carbon
12.0107

Limiting Reagent Lab

Name: _____

Goal: To identify the limiting reactant in a precipitation reaction and predict how much product will be made.

Materials:

- 0.30 grams of $CaCl_2$
- solid Na_2CO_3 (choose an amount between 0.1 and 1.0 grams)

Safety:

- Wear goggles until your lab bin is put away.
- $CaCl_2$ and Na_2CO_3 are moderately toxic if ingested and can cause rash on your skin. Be careful with these reagents.
- Wash your hands before leaving class.

Pre-Lab:

1. Predict the products and balance the equation for the reaction that we will be doing today:

   $CaCl_2$ + Na_2CO_3 →

2. What type of reaction are we doing? (Classify the reaction) _____

3. We are planning to isolate the product of this reaction today. Remember, the product in these reactions is always the precipitate. Which of the two products is going to precipitate? _____(Use your solubility chart.) ***Record this answer in the blanks in table 1 and add state symbols to your balanced equation***.

Procedure: There is none. Science is about exploring, thinking, trying, messing up, trying again, and succeeding. You have the knowledge, ingenuity, and the background to figure this out on your own. Remember: Our goal is to react the two reactants to make a precipitate. We will need to isolate the precipitate to get a mass of the product.

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Procedure: (Record what you decided to do here. Bullet points are fine, but ***include enough detail so that somebody else could repeat what you did on their own***. What equipment did you use? How much of each chemical? What is the first step? The second?.... etc.)

Data: Design a data table. Choose a logical format. Be sure to include **ALL** values that you recorded from the balance.

Table 1.

Calculations: (Determine what was the limiting reagent.)

(Determine how much product we are expecting.)

Post-Lab Problem: Determine how much of the excess reagent was left over after the reaction.

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12
C
Carbon
12.0107

Solutions Practice

1. Calculate the mass of water produced when 0.333 L of 0.500 M NaOH is added to 3.0 grams of acetic acid. The equation is:

$$NaOH(aq) + HC_2H_3O_2(aq) \rightarrow NaC_2H_3O_2(aq) + H_2O(l)$$

2. Calculate the number of grams of AgCl formed when 0.200 L of 0.200 M $AgNO_3$ is added to 75.0 grams of $CaCl_2$. The equation is:

$$2\ AgNO_3(aq) + CaCl_2(aq) \rightarrow 2\ AgCl(s) + Ca(NO_3)_2(aq)$$

3. Calculate the mass of AgCl formed when 0.250 L of 0.100 M solution of NaCl is added to 0.100 L of 0.200 M $AgNO_3$.

$$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$$

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4. Calculate the mass of $BaSO_4$ formed when 0.875 L of 0.200 M Na_2SO_4 solution is added to 0.500 L of 0.500 M $BaCl_2$ solution.

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow 2\ NaCl(aq) + BaSO_4(s)$$

Percent Yield Practice

Answer the following questions in the space provided. <u>SHOW ALL WORK!</u>

1. When 84.8 g of iron (III) oxide reacts with excess carbon monoxide, then 57.8 g of iron is produced:

$$Fe_2O_3 + 3CO_{(g)} \rightarrow 2Fe_{(s)} + 3CO_{2(g)}$$

What is the percent yield of this reaction?

2. When 50.0 g of silicon dioxide is heated with excess of carbon, 32.2 g of silicon carbide is produced.

$$SiO_{2(s)} + 3C_{(s)} \rightarrow SiC_{(s)} + 2CO_{(g)}$$

What is the percent yield of this reaction?

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Notice that in these two problems, you will have to determine the limiting reagent first.

3. **Lithium nitride reacts with water to form ammonia and aqueous lithium hydroxide.**

$$Li_3N_{(s)} + 3H_2O_{(l)} \rightarrow NH_{3(g)} + 3LiOH_{(aq)}$$

A student reacted 98.7 g of Li_3N and 162.18 g of H_2O and obtained 159.69 g of LiOH. What was the percent yield of this reaction?

4. **Carbon monoxide and hydrogen gas combine to form methanol by the following reaction:**

$$CO_{(g)} + 2H_{2(g)} \rightarrow CH_3OH_{(g)}$$

If 5.00 g of carbon monoxide reacted with 0.61 g of hydrogen gas, and 4.50 g of methanol is obtained, what is the percent yield of this reaction?

Excess Reagent Left Over Practice

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

1. When 10.0 g of C_2H_2 are reacted with 15.0 g of O_2, which is the limiting reagent?

2. How many **moles** of the excess reagent will be **consumed** (used) in the reaction?

3. How many **moles** of the excess reagent **remain** at the end of the reaction?

4. How many **grams** of the excess reagent remain at the end of the reaction?

Balance the following equation:

$$___CS_2\ (g) + ___Cl_2\ (g) \rightarrow ___CCl_4\ (l) + ___S_2Cl_2\ (l)$$

5. What is the limiting reagent when 6.00 g of CS_2 gas react with 10.0 g of Cl_2 gas in this reaction?

6. How many **moles** of the excess reagent will be **consumed** (used) in the reaction?

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7. How many **moles** of the excess reagent **remain** at the end of the reaction?

8. How many **grams** of the excess reagent remain at the end of the reaction?

Balance the following equation:

$$____Ca + ____O_2 \rightarrow ____CaO$$

9. What is the limiting reagent when 4.00 g of Ca solid react with 16 L of O_2 gas in this reaction?

10. How many **moles** of the excess reagent will be **consumed** (used) in the reaction?

11. How many **moles** of the excess reagent **remain** at the end of the reaction?

12. How many **grams** of the excess reagent remain at the end of the reaction?