**Name** _____

# #8 Stoichiometry
## Quantitative Chemistry

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### Student Learning Map

**Unit EQ: How do we use balanced chemical equations to determine the mole relationship between reactants and products?**

**Key Learning: Substances in a balanced chemical equation have a defined relationship to one another.**

**UNIT CONCEPT:**

| 1. Mole-Mole Relationships | 2. Limiting Reactants | 3. Percent Yield |
|---|---|---|
| **LESSON ESSENTIAL QUESTIONS:** | | |
| How do I use the balanced chemical equation to convert from one substance to another? | a. How does the limiting reactant dictate the amount of product formed?<br><br>b. How do I determine the quantity of excess reactant(s)? | How do I calculate percent yield to determine my success in the laboratory? |
| **LESSON ESSENTIAL VOCABULARY:** | | |
| Mole-Mole Ratio<br>(Stoichiometric Step)<br>Stoichiometry | Limiting Reactant<br>Excess Reactant | Percent Yield<br>Experimental Yield<br>Theoretical Yield |

Date:

# 1. Mole-Mole Relationships

***EQ: How do I use the balanced chemical equation to convert from one substance to another?***

Stoichiometry involves converting from one element/compound to another using MOLE ratios. These mole ratios are set up using the coefficients from the chemical equation.

Think of it as a recipe. For example, if we were making a batch of brownies, we could write an equation as follows:

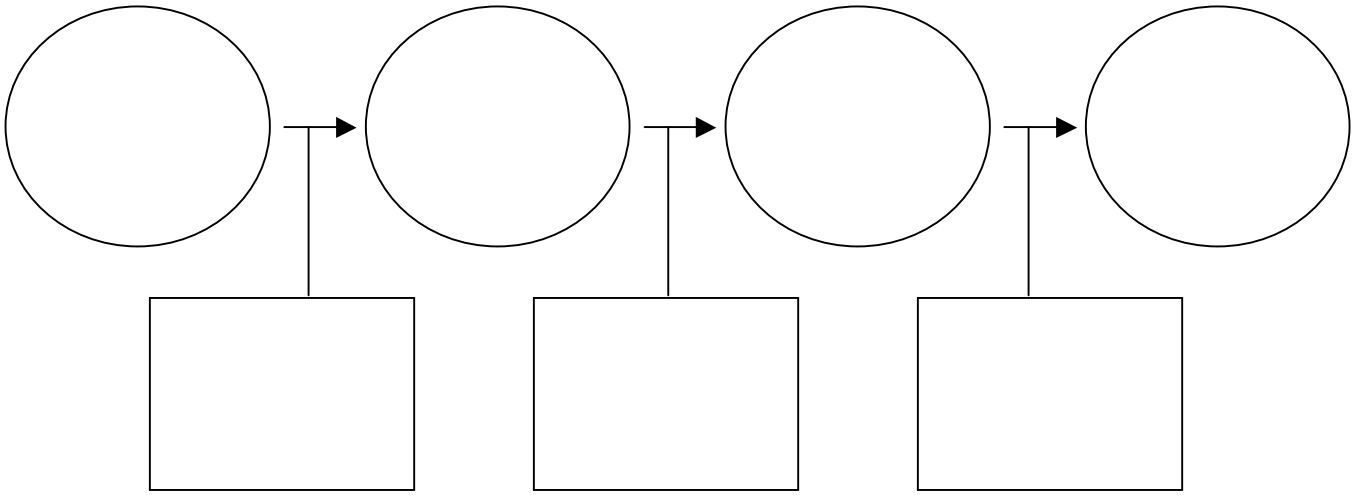
4 Eggs + 1 Cup Water + 1 Cup Oil + 1 Large Powder Mix → 64 Brownies

The coefficients are the numbers in the front of each ingredient or product. What if we only wanted to make 32 brownies? How many eggs would we need? Although this seems simple, we can set up a fence-posting problem as follows:

What if we used only 1 egg? How many brownies could we make?

*WE CAN USE THE SAME CONCEPT FOR CHEMICAL REACTIONS.*

Conversion Roadmap:



Date:

# 1. Mole-Mole Relationships (cont.)

## A. Mole-Mole Conversions (One-Step)

*It only takes one step to go from moles of one substance to moles of another. Use coefficient ratios to solve these.*

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

   a) Balance the equation.

   b) How many moles of HCl are required to react with 0.20 moles Zn?

   c) If 3.0 moles HCl reacted, how many moles of $ZnCl_2$ would be produced?

2. $Fe + O_2 \rightarrow Fe_2O_3$

   a) Balance the equation.

   b) How many moles of iron are required to react with 0.050 moles $O_2$?

   c) If 0.050 moles $O_2$ reacted, how many moles of $Fe_2O_3$ would be produced?

3. $Al + Cl_2 \rightarrow AlCl_3$

   a) Balance the equation.

   b) How many moles of Al would be needed to produce 0.88 moles $AlCl_3$?

   c) How many moles of $Cl_2$ would be needed to produce 0.88 moles $AlCl_3$?

Date:

# 1. Mole-Mole Relationships (cont.)

Demo:

Review: If 3.25 moles of $H_2O$ reacted, how many moles of acetylene gas would be produced?

## *B. Gram-Mole Conversions (Two-Step)*

*What if we start with grams instead of moles?*

*It takes two steps to go from grams of one substance to moles of another. The first step will involve the conversion 1 mole = _____ g (atomic/molar mass), and the second step will use the coefficient ratio.*

a) How many moles of acetylene gas can be produced from 100. grams of water?

b) If 25.0 grams of $CaC_2$ react, how many moles of $Ca(OH)_2$ will be produced?

2. $Cr + S_8 \rightarrow Cr_2S_3$

a) Balance the equation.

b) How many moles of $S_8$ are required to react with 100. grams Cr?

c) How many moles of $S_8$ are needed to produce 85 grams $Cr_2S_3$?

Date:

# 1. Mole-Mole Relationships (cont.)

## C. Mole-Gram Conversions (Two-Step)

*What if we start with moles but need to convert to grams?*

*It takes two steps to go from moles of one substance to grams of another. The first step would use the coefficient ratio, and the second step would involve 1 mole = _____ g (atomic/molar mass).*

Demo:

a) If 1.05 moles of $C_2H_2$ reacted, how many grams of $O_2$ would be needed?

b) If 1.05 moles of $C_2H_2$ reacted, how many grams of $CO_2$ would be produced?

2. $MnO_2 + Al \rightarrow Mn + Al_2O_3$

a) Balance the equation.

b) If 4.6 moles of $MnO_2$ reacted, how many grams of $Al_2O_3$ would be produced?

c) How many grams of Al would be needed to produce 0.98 moles of Mn?

d) How many grams of Mn can be produced from 0.86 moles $MnO_2$?

Date:

# 1. Mole-Mole Relationships (cont.)

## *Mixed Review (1-step & 2-step)*

1. $Al_2O_3$ + Ba → BaO + Al

   a) Balance the equation.

   b) If 3.25 moles of $Al_2O_3$ reacted, how many moles of barium would be needed?

   c) How many moles of BaO would be produced along with 23.0 grams Al?

   d) How many grams of Ba are needed to produce 1.4 moles BaO?

2. Al + HCl → $H_2$ + $AlCl_3$

   a) Balance the equation.

   b) How many moles of Al would be needed to produce 0.88 moles $AlCl_3$?

   c) How many moles of HCl would be needed to produce 1.33 moles $H_2$?

   d) How many moles of $H_2$ would be produced from 14 grams Al?

   e) How many grams of $AlCl_3$ would be produced if 2.00 moles HCl reacted?

Date:

# 1. Mole-Mole Relationships (cont.)

## D. Gram-Gram Conversions (Three-Step)

*How do we convert from grams of one substance to grams of another?*

*It takes three steps to go from grams of one substance to grams of another. The first step involves 1 mol = ____ g, the second step uses coefficient ratios, and the last step involves 1 mol = ____ g.*

1. $Ba + N_2 \rightarrow Ba_3N_2$

   a) Balance the equation.

   b) How many grams of Ba would be needed to produce 86.6 grams $Ba_3N_2$?

   c) How many grams of Ba would be required to react with 30.0 grams $N_2$?

2. $Cl_2 + KI \rightarrow KCl + I_2$

   a) Balance the equation.

   b) If 0.92 grams of $Cl_2$ reacted, how many grams of KCl would be produced?

   c) If 38.65 grams of KI reacted, how many grams of $I_2$ would be produced?

Date:

# 1. Mole-Mole Relationships (cont.)

## Mixed Review (A, B, C, & D)

1. $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$

   a) Balance the equation.

   b) How many moles of $O_2$ would be needed to react with 0.50 moles $C_2H_6$?

   c) If 136.8 grams of $C_2H_6$ reacted, how many moles of $CO_2$ would be produced?

   d) If 2.0 moles of $O_2$ reacted, how many grams of water would be produced?

   e) How many grams of $C_2H_6$ are needed to produce 18.0 grams $CO_2$?

2. $ZnS + O_2 \rightarrow ZnO + SO_2$

   a) Balance the equation.

   b) If 0.922 moles of ZnS reacted, how many moles of ZnO would be produced?

   c) If 2.33 moles of $O_2$ reacted, how many grams of $SO_2$ would be produced?

   d) How many grams of $O_2$ would be needed to produce 78.10 grams $SO_2$?

Date:

# 2a. Limiting Reactants

***EQ: How does the limiting reactant dictate the amount of product formed?***

Picture an assembly line. Let's say we are making goodie bags to hand out to elementary school students. We are putting 1 small toy, 1 candy bar, 2 packs of gum, and 5 stickers in each bag.

Equation: 1 toy + 1 candy bar + 2 gum packs + 5 stickers → 1 goodie bag

Four students sitting at the same lab table will create this. At lab table #1, George has 5 toys, Joey has 6 candy bars, Kristen has 8 packs of gum, and Tom has 30 stickers.

How many bags could George make? _____

How many bags could Joey make? _____

How many bags could Kristen make? _____

How many bags could Tom make? _____

So, as a group, what is the MOST number of COMPLETE bags they could make? _____

Which object/person LIMITS the number of bags they could make? _____

**The same concept can be applied to chemical reactions.**

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## *Example*

Consider the following equation:

$2Na + Cl_2 \rightarrow 2NaCl$

Pretend we had 1.5 moles of Na AND 1.5 moles of $Cl_2$.

Just using Na, how many moles of NaCl could be created?

Just using $Cl_2$, how many moles of NaCl could be created?

Which reactant creates the least amount of NaCl? _____

Sodium is our limiting reactant! Just like we could only make 4 bags from 8 packs of gum (the gum was used up, and we had leftovers of everything else), we can only create 1.5 moles of NaCl (the Na was used up, and we had leftover (excess) $Cl_2$).

Date:

# 2a. Limiting Reactants (cont.)

*Rules for determining the limiting reactant:*

1. Balance the equation.
2. Use the amount given of Reactant 1 to determine the MOLES it could produce of the first product.
3. Use the amount given of Reactant 2 to determine the MOLES it could produce of the first product.
4. If Reactant 1 produces LESS moles of the product than Reactant 2, than Reactant 1 is the limiting reactant. Otherwise, Reactant 2 is the limiting reactant.
5. To determine the amount of product that is produced, use the LIMITING REACTANT.

*Example #1*

1.67 moles of Cr react with 1.33 moles of $S_8$ according to the equation below:

$$16Cr + 3S_8 \rightarrow 8Cr_2S_3$$

*Convert Reactant #1 to moles of Product #1. (The product that is listed first.)*

*Convert Reactant #2 to moles of Product #1. (The product that is listed first.)*

*Limiting Reactant =* _____ *Excess Reactant =* _____

*How many moles of the product would be produced?* _____

*Example #2*

0.55 moles of Mg react with 0.55 moles of HCl according to the equation below:

$$Mg + 2HCl \rightarrow H_2 + MgCl_2$$

*Convert Reactant #1 to moles of Product #1 which is $H_2$ in this case.*

*Convert Reactant #2 to moles of Product #1 which is $H_2$ in this case.*

*Limiting Reactant =* _____ *Excess Reactant =* _____

*How many moles of $H_2$ would be produced?* _____

Date:

# 2a. Limiting Reactants (cont.)

## Example #3

2.56 moles of As react with 1.79 moles of $I_2$ according to the equation below:

$As + I_2 \rightarrow AsI_3$

*Balance the equation.*

*Convert Reactant #1 to moles of Product #1.*

*Convert Reactant #2 to moles of Product #1.*

*Limiting Reactant =* _____ *Excess Reactant =* _____

*How many moles of the product would be produced?*_____

## Example #4

2.67 moles of $PCl_5$ react with 1.23 moles of $H_2O$ according to the equation below:

$PCl_5 + H_2O \rightarrow H_3PO_4 + HCl$

*Balance the equation.*

*Convert Reactant #1 to moles of Product #1.*

*Convert Reactant #2 to moles of Product #1.*

*Limiting Reactant =* _____ *Excess Reactant =* _____

*How many moles of $H_3PO_4$ would be produced?*_____

Date:

# 2a. Limiting Reactants (cont.)

## Example #5

4.78 moles of $Fe_3O_4$ react with 18.79 moles of $H_2$ according to the equation below:

$$Fe_3O_4 + H_2 \rightarrow Fe + H_2O$$

*Balance the equation.*

*Convert Reactant #1 to moles of Product #1.*

*Convert Reactant #2 to moles of Product #1.*

*Limiting Reactant =* _____ *Excess Reactant =* _____

*How many moles of Fe would be produced?* _____

## Example #6

1.0 mole of $C_3H_8$ reacts with 2.0 moles of $O_2$ according to the equation below:

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

*Balance the equation.*

*Convert Reactant #1 to moles of Product #1.*

*Convert Reactant #2 to moles of Product #1.*

*Limiting Reactant =* _____ *Excess Reactant =* _____

*How many moles of $CO_2$ would be produced?* _____

Date:

# 2a. Limiting Reactants (cont.)

## Example #7

16.78 grams of $C_4H_{10}$ react with 32.0 grams of $O_2$ according to the equation below:

$$C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$$

*Balance the equation.*

*Convert Reactant #1 to moles of Product #1. (You are starting with grams!)*

*Convert Reactant #2 to moles of Product #1. (You are starting with grams!)*

*Limiting Reactant =* _____ *Excess Reactant =* _____

*How many GRAMS of $CO_2$ would be produced?*

## Example #8

4.0 grams of K react with 100. grams of $H_2O$ according to the equation below:

$$K + H_2O \rightarrow KOH + H_2$$

*Balance the equation.*

*Determine the limiting reactant.*

*What is the excess reactant?* _____

*How many GRAMS of KOH would be produced?*

Date:

# 2a. Limiting Reactants (cont.)

*Example #9*

How many grams of copper(II) oxide can be produced from the reaction involving 16.0 grams of copper and 20.0 grams of oxygen?

$Cu + O_2 \rightarrow CuO$

*Example #10*

How many grams of $AlBr_3$ can be produced when 35 grams of Al react with 45 grams of $Br_2$?

$Al + Br_2 \rightarrow AlBr_3$

*Example #11*

How many grams of $Li_2CO_3$ can be produced from the reaction involving 10.0 grams of LiOH and 50.0 grams of $CO_2$?

$LiOH + CO_2 \rightarrow Li_2CO_3 + H_2O$

Date:

# 2b. Excess Reactants

***EQ: How do I determine the quantity of excess reactant(s)?***

To determine the amount of excess reactant(s) remaining, you will need to determine the amount of reactant that was *actually used*. Then, take the difference from the original amount given.

For example, in our original example of goodie bags, Kristen limited the total number of bags made (4) since she ran out of packs of gum. Originally, she had 8 packs of gum, while George had 5 toys, Joey had 6 candy bars, and Tom had 30 stickers.

Equation: 1 toy + 1 candy bar + 2 gum packs + 5 stickers → 1 goodie bag

If we wanted to calculate the amount of stickers left over, we could use a stoichiometric problem:

$$8 \text{ gum packs} \times \frac{5 \text{ stickers}}{2 \text{ gum packs}} = 20 \text{ stickers}$$

*This is the limiting reactant!* *This is how many were used!*

Since Tom had 30 stickers originally, we can subtract 20 from 30, and we would have 10 stickers remaining.

*Rules for determining the quantity of excess reactant remaining:*

1. Determine the limiting reactant.
2. Use the limiting reactant to find the amount USED of the excess reactant. (Set up a stoichiometric problem to convert from limiting reactant to excess reactant.)
3. Subtract AMOUNT USED from AMOUNT GIVEN (in the problem). This is the amount left over.

*Example #1*

1.0 mole of $CS_2$ reacts with 1.0 mole $O_2$ according to the equation below.

$$CS_2 + O_2 \rightarrow CO_2 + SO_2$$

*Balance the equation.*

*Determine the limiting reactant.*

*Determine the MOLES USED of excess reactant.*

*Calculate the remaining moles of excess reactant. (GIVEN – USED)*

Date:

# 2b. Excess Reactants (cont.)

*Example #2*

15.0 grams of Al react with 8.0 grams $Br_2$ according to the equation below.

$Al + Br_2 \rightarrow AlBr_3$

*Balance the equation.*

*Determine the limiting reactant.*

*Determine the GRAMS USED of excess reactant.*

*Calculate the remaining mass of excess reactant.*

*Example #3*

100. grams of $I_2$ react with 50.0 grams $Cl_2$ according to the equation below.

$I_2 + Cl_2 \rightarrow ICl$

*Balance the equation.*

*Determine the limiting reactant.*

*Determine the GRAMS USED of excess reactant.*

*Calculate the remaining mass of excess reactant.*

Date:

# 3. Percent Yield

***EQ: How do I calculate percent yield to determine my success in the laboratory?***

Terms:

Experimental (Actual) Yield –

Theoretical Yield –

| **PERCENT YIELD** |
| --- |
| |

Problems:

1. (From Demo)

2. A student is performing a lab where he synthesizes and collects silver chloride. According to his calculations, he should collect 10.81 grams AgCl, but when the substance dries, only 10.23 grams are left on the filter paper. What is his percent yield?

3. A chemist needs to create 5.00 grams hydrogen sulfide. If the reaction she is using only has a 77% yield, how many grams should she theoretically plan on producing?

Date:

# REVIEW

| **Flowchart:** | |
|---|---|
| **Basic Stoichiometry Problems**<br>Data is given about only 1 reactant; the others are assumed to be in excess. | **Limiting Reactant Problems**<br>Data is given about 2 or more reactants. |
| **Excess Reactant Problems** | **Percent Yield Problems** |

**Review Problem:**
In the reaction below, 5.00 grams of iron combine with 100. grams of oxygen.

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

1. What is the limiting reactant?

2. How many grams of ferric oxide can be produced?

3. What is the excess reactant? _____ How many grams of it remain?

4. If only 4.7 grams of ferric oxide are collected, what is the percent yield?