Name Answer Key

#8 Stoichiometry

Quantitative Chemistry

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? 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 (Stoichiometric Step) Stoichiometry	Limiting Reactant Excess Reactant	Percent Yield Experimental Yield 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:

$$32 \text{ brownies} \times \frac{4 \text{ eggs}}{64 \text{ brownies}} = 2 \text{ eggs}$$

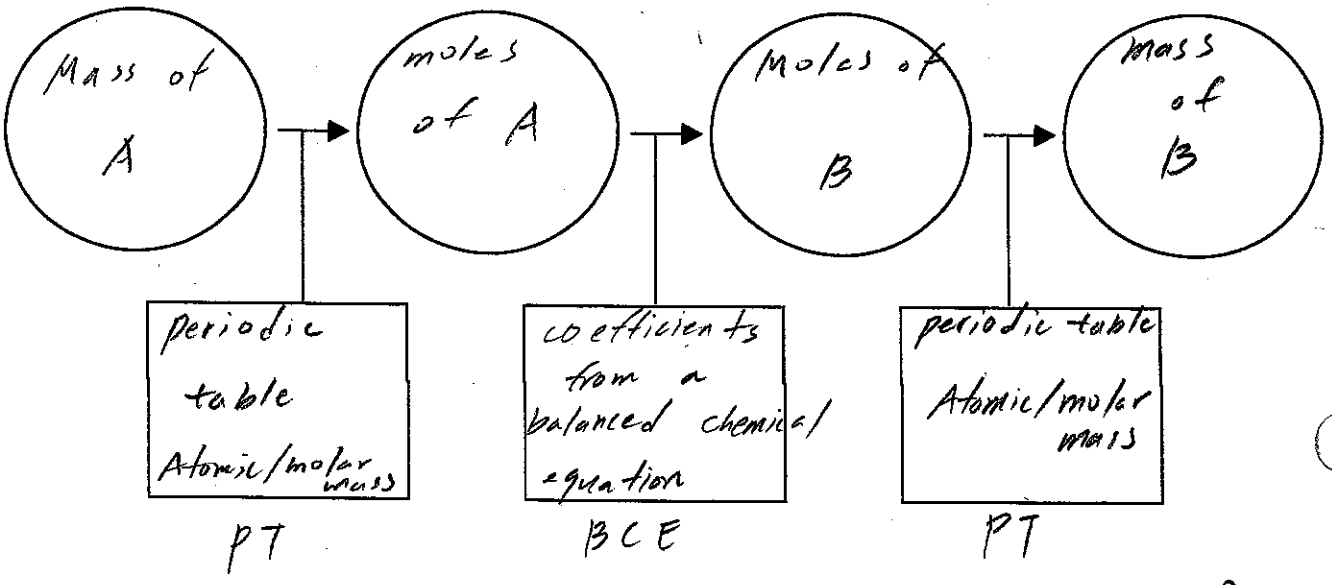
What if we used only 1 egg? How many brownies could we make?

$$1 \text{ egg} \times \boxed{\frac{64 \text{ brownies}}{4 \text{ egg}}} = 16 \text{ brownies}$$

WE CAN USE THE SAME CONCEPT FOR CHEMICAL REACTIONS.

balanced chemical equation.

Conversion Roadmap:



solids $gA \times \underset{pt}{\frac{mol A}{g A}} \times \underset{BCE}{\frac{mol B}{mol A}} \times \underset{pt}{\frac{g B}{mol B}} = g B$

Date:

1. Mole-Mole Relationships (cont.)

Liquid $mL A \times \underset{Density}{\frac{g A}{mL A}} \times \underset{pt}{\frac{mol A}{g A}} \times \underset{bcE}{\frac{mol B}{mol A}} \times \underset{pt}{\frac{g}{mo}}$

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.

Solutions $L A \times \underset{molarity}{\frac{mol A}{L A}} \times \frac{mol B}{mol A} \times \frac{g B}{mol B}$ g

1. $1 Zn + 2 HCl \rightarrow 1 ZnCl_2 + 1 H_2$

   a) Balance the equation.

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

   $0.20 \text{ mol Zn} \times \frac{2 \text{ mol HCl}}{1 \text{ mol Zn}} = 0.40 \text{ mol HCl}$

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

   $3.0 \text{ mol HCl} \times \frac{1 \text{ mol } ZnCl_2}{2 \text{ mol HCl}} = 1.5 \text{ mol } ZnCl_2$

Gas (stp) : $L A \times \frac{1 \text{ mol } A}{22.4 \text{ l } A} \times \frac{mol B}{mol A} \times \frac{g B}{mol B}$ g B.

2. $4 Fe + 3 O_2 \rightarrow 2 Fe_2O_3$

   a) Balance the equation.

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

   $0.050 \text{ mol } O_2 \times \frac{4 \text{ mol Fe}}{3 \text{ mol } O_2} = 0.067 \text{ mol Fe}$

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

   $0.050 \text{ mol } O_2 \times \frac{2 \text{ mol } Fe_2O_3}{3 \text{ mol } O_2} = 0.033 \text{ mol } Fe_2O_3$

3. $2 Al + 3 Cl_2 \rightarrow 2 AlCl_3$

   a) Balance the equation. don't reduce.

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

   $0.88 \text{ mol } AlCl_3 \times \frac{2 \text{ mol Al}}{2 \text{ mol } AlCl_3} = 0.88 \text{ mol Al}$

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

   $0.88 \text{ mol } AlCl_3 \times \frac{3 \text{ mol } Cl_2}{2 \text{ mol } AlCl_3} = 1.32 \text{ mol } Cl_2$

   2 sig fig

Date:

1. Mole-Mole Relationships (cont.)

Review of Balancing Chemical Equations:
If 3.25 moles of H_2O reacted, how many moles of acetylene (C_2H_2) gas would be produced?

$\underline{1}\ CaC_2 + \underline{2}\ H_2O \rightarrow \underline{1}\ \underset{2\ 2}{Ca(OH)_2} + \underline{1}\ C_2H_2$

$$3.25 \text{ mol } H_2O \times \frac{1 \text{ mol } C_2H_2}{2 \text{ mol } H_2O} = 1.63 \text{ mol } C_2H_2$$

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 $\overset{C_2H_2}{\text{acetylene}}$ gas can be produced from 100. grams of water?

$$100.\ g\ H_2O \times \frac{1 \text{ mol } H_2O}{18.02 g\ H_2O} \times \frac{1 \text{ mol } C_2H_2}{2 \text{ mol } H_2O} = 2.77 \text{ mol } C_2H_2$$

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

$$25.0 g\ CaC_2 \times \frac{1 \text{ mol } CaC_2}{64.10 g\ CaC_2} \times \frac{1\ Ca(OH)_2}{1 \text{ mol } CaC_2} = 0.390 \text{ mol } Ca(OH)_2$$

2. $16\ Cr + 3\ S_8 \rightarrow 8\ \underset{16\ \ 24}{Cr_2S_3}$

a) Balance the equation.

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

$$100.\ g\ Cr \times \frac{1 \text{ mol } Cr}{51.10 g\ Cr} \times \frac{3 \text{ mol } S_8}{16 \text{ mol } Cr} = 0.367 \text{ mol } S_8$$

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

$$85 g\ Cr_2S_3 \times \frac{1 \text{ mol } Cr_2S_3}{200.2 g\ Cr_2S_3} \times \frac{3 \text{ mol } S_8}{8 \text{ mol } Cr_2S_3} = 0.16 \text{ mol}4\ S_8$$

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).

Example: $2C_2H_2 + 5O_2 = 2H_2O + 4CO_2$

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

$$1.05 \text{ mol } C_2H_2 \times \frac{5 \text{ mol } O_2}{2 \text{ mol } C_2H_2} \times \frac{32.0 \text{ g } O_2}{1 \text{ mol } O_2} = 84.0 \text{ g } O_2$$

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

$$1.05 \text{ mol } C_2H_2 \times \frac{4 \text{ mol } CO_2}{2 \text{ mol } C_2H_2} \times \frac{44.0 \text{ g } CO_2}{1 \text{ mol } CO_2} = 92.4 \text{ g } CO_2$$

2. $3\ MnO_2 + 4\ Al \rightarrow 3\ Mn + 2\ Al_2O_3$

a) Balance the equation.

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

$$4.6 \text{ mol } MnO_2 \times \frac{2 \text{ mol } Al_2O_3}{3 \text{ mol } MnO_2} \times \frac{102. \text{ g } Al_2O_3}{1 \text{ mol } Al_2O_3} = 312.8 \text{ g } Al_2O_3$$

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

$$0.98 \text{ mol } Mn \times \frac{4 \text{ mol } Al}{3 \text{ mol } Mn} \times \frac{27.0 \text{ g } Al}{1 \text{ mol } Al} = 35 \text{ g } Al$$

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

$$0.86 \text{ mol } MnO_2 \times \frac{3 \text{ mol } Mn}{3 \text{ mol } MnO_2} \times \frac{54.9 \text{ g } Mn}{1 \text{ mol } Mn} = 47 \text{ g } Mn$$

Date:

1. Mole-Mole Relationships (cont.)

Mixed Review (1-step & 2-step)

1. $1\ Al_2O_3 + 3\ Ba \rightarrow 3\ BaO + 2\ Al$

   a) Balance the equation.

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

   $$3.25\ mol\ Al_2O_3 \times \frac{3\ mol\ Ba}{1\ mol\ Al_2O_3} = 9.75\ mol\ Ba$$

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

   $$23.0\ g\ Al \times \frac{1\ mol\ Al}{26.98\ g\ Al} \times \frac{3\ mol\ BaO}{2\ mol\ Al} = 1.28\ mol\ BaO$$

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

   $$1.4\ mol\ BaO \times \frac{3\ mol\ Ba}{3\ mol\ BaO} \times \frac{137\ g\ Ba}{1\ mol\ Ba} = 192\ g\ Ba$$

2. $2Al + 6HCl \rightarrow 3H_2 + 2AlCl_3$

   a) Balance the equation.

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

   $$0.88\ mol\ AlCl_3 \times \frac{2\ mol\ Al}{2\ mol\ AlCl_3} = 0.88\ mol\ Al$$

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

   $$1.33\ mol\ H_2 \times \frac{6\ mol\ HCl}{3\ mol\ H_2} = 2.66\ mol\ HCl$$

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

   $$14\ g\ Al \times \frac{1\ mol\ Al}{27.0\ g\ Al} \times \frac{3\ mol\ H_2}{2\ mol\ Al} = 0.78\ mol\ H_2$$

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

   $$2.00\ mol\ HCl \times \frac{2\ mol\ AlCl_3}{6\ mol\ HCl} \times \frac{133\ g\ AlCl_3}{1\ mol\ AlCl_3} = 88.7\ g\ AlCl_3$$

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. $3Ba + 1N_2 \rightarrow 1\ Ba_3N_2$

   a) Balance the equation.

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

$$86.6g\ Ba_3N_2 \times \frac{1\ mol\ Ba_3N_2}{440.0g\ Ba_3N_2} \times \frac{3\ mol\ Ba}{1\ mol\ Ba_3N_2} \times \frac{137.3g\ Ba}{1\ mol\ Ba} = 81.1\ g\ Ba$$

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

$$30.0g\ N_2 \times \frac{1\ mol\ N_2}{28.01g\ N_2} \times \frac{3\ mol\ Ba}{1\ mol\ N_2} \times \frac{137.3g\ Ba}{1\ mol\ Ba} = 441g\ Ba$$

2. $1\ Cl_2 + 2KI \rightarrow 2KCl + 1\ I_2$

   a) Balance the equation.

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

$$0.92g\ Cl_2 \times \frac{1\ mol\ Cl_2}{70.9g\ Cl_2} \times \frac{2\ mol\ KCl}{1\ mol\ Cl_2} \times \frac{74.6g\ KCl}{1\ mol\ KCl} = 1.9\ g\ KCl$$

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

$$38.65g\ KI \times \frac{1\ mol\ KI}{166.00g\ KI} \times \frac{1\ mol\ I_2}{2\ mol\ KI} \times \frac{253.80g\ I_2}{1\ mol\ I_2} = 29.55g\ I_2$$

Date:

1. Mole-Mole Relationships (cont.)

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

1. $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$

4 12 14 4 8 12 6

   a) Balance the equation.

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

$$0.50\text{ mol }C_2H_6 \times \frac{7\text{ mol }O_2}{2\text{ mol }C_2H_6} = 1.8\text{ mol }O_2$$

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

$$136.8\text{ g }C_2H_6 \times \frac{1\text{ mol }C_2H_6}{30.07\text{ g }C_2H_6} \times \frac{4\text{ mol }CO_2}{2\text{ mol }C_2H_6} = 9.097\text{ g mol }CO_2$$

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

$$2.0\text{ mol }O_2 \times \frac{6\text{ mol }H_2O}{7\text{ mol }O_2} \times \frac{18.0\text{ g }H_2O}{1\text{ mol }H_2O} = 31\text{ g }H_2O$$

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

$$18.0\text{ g }CO_2 \times \frac{1\text{ mol }CO_2}{44.00\text{ g }CO_2} \times \frac{2\text{ mol }C_2H_6}{4\text{ mol }CO_2} \times \frac{30.07\text{ g }C_2H_6}{1\text{ mol }C_2H_6} = 6.15\text{ g }C_2H_6$$

2. $2\,ZnS + 3O_2 \rightarrow 2\,ZnO + 2\,SO_2$

2 4

   a) Balance the equation.

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

$$0.922\text{ mol }ZnS \times \frac{2\text{ mol }ZnO}{2\text{ mol }ZnS} = 0.922\text{ mol }ZnO$$

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

$$2.33\text{ mol }O_2 \times \frac{2\text{ mol }SO_2}{3\text{ mol }O_2} \times \frac{64.06\text{ g }SO_2}{1\text{ mol }SO_2} = 99.5\text{ g }SO_2$$

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

$$78.10\text{ g }SO_2 \times \frac{1\text{ mol }SO_2}{64.065\text{ g }SO_2} \times \frac{3\text{ mol }O_2}{2\text{ mol }SO_2} \times \frac{31.998\text{ g }O_2}{1\text{ mol }O_2} = 58.51\text{ g }O_2$$

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? 5

How many bags could Joey make? 6

How many bags could Kristen make? 4

How many bags could Tom make? 6

So, as a group, what is the MOST number of COMPLETE bags they could make? 4

Which object/person LIMITS the number of bags they could make? Kristen's

The same concept can be applied to chemical reactions.

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?

$$1.5 mol\ Na \times \frac{2\ mol\ NaCl}{2\ mol\ Na} = 1.5\ mol\ NaCl$$

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

$$1.5\ mol\ Cl_2 \times \frac{2\ mol\ NaCl}{1\ mol\ Cl_2} = 3.0\ mol\ NaCl$$

Which reactant creates the least amount of NaCl? Na

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.)

$$1.67\,mol\,Cr \times \frac{8\,mol\,Cr_2S_3}{16\,mol\,Cr} = 0.84\,mol\,Cr_2S_3$$

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

$$1.33\,mol\,S_8 \times \frac{8\,mol\,Cr_2S_3}{3\,mol\,S_8} = 3.55\,mol\,Cr_2S_3$$

Limiting Reactant = Cr *Excess Reactant =* S_8

How many moles of the product would be produced? 0.84 mol Cr_2S_3

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.

$$0.55\,mol\,Mg \times \frac{1\,mol\,H_2}{1\,mol\,Mg} = 0.55\,mol\,H_2$$

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

$$0.55\,mol\,HCl \times \frac{1\,mol\,H_2}{2\,mol\,HCl} = 0.28\,mol\,H_2$$

Limiting Reactant = HCl *Excess Reactant =* Mg

How many moles of H_2 would be produced? 0.28 mol H_2

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:

$$2\,As + 3\,I_2 \rightarrow 2\,AsI_3$$

Balance the equation.

Convert Reactant #1 to moles of Product #1.

$$2.56 \text{ mol } As \times \frac{2 \text{ mol } AsI_3}{2 \text{ mol } As} = 2.56 \text{ mol } AsI_3$$

Convert Reactant #2 to moles of Product #1.

$$1.79 \text{ mol } I_2 \times \frac{2 \text{ mol } AsI_3}{3 \text{ mol } I_2} = 1.19 \text{ mol } AsI_3$$

Limiting Reactant = I_2 *Excess Reactant =* As

How many moles of the product would be produced? 1.19 mol AsI_3

Example #4

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

$$1\,PCl_5 + 4\,H_2O \rightarrow 1\,H_3PO_4 + 5\,HCl$$

8 4 3 1 4 5

Balance the equation.

Convert Reactant #1 to moles of Product #1.

$$2.67 \text{ mol } PCl_5 \times \frac{1 \text{ mol } H_3PO_4}{1 \text{ mol } PCl_5} = 2.67 \text{ mol } H_3PO_4$$

Convert Reactant #2 to moles of Product #1.

$$1.23 \text{ mol } H_2O \times \frac{1 \text{ mol } H_3PO_4}{4 \text{ mol } H_2O} = 0.31 \text{ mol } H_3PO_4$$

Limiting Reactant = H_2O *Excess Reactant =* PCl_5

How many moles of H_3PO_4 *would be produced?* 0.31 mol H_3PO_4

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:

$$1\,Fe_3O_4 \quad + 4H_2 \quad \rightarrow 3Fe \quad + 4H_2O$$

Balance the equation.

Convert Reactant #1 to moles of Product #1.

$$4.78\text{ mol } Fe_3O_4 \times \frac{3\text{ mol } Fe}{1\text{ mol } Fe_3O_4} = 14.3\text{ mol } Fe.$$

Convert Reactant #2 to moles of Product #1.

$$18.79\text{ mol } H_2 \times \frac{3\text{ mol } Fe}{4\text{ mol } H_2} = 14.09\text{ mol } Fe$$

Limiting Reactant = H_2 *Excess Reactant* = Fe_3O_4

How many moles of Fe would be produced? 14.09 mol Fe

Example #6

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

$$1\,C_3H_8 \quad + 5O_2 \quad \rightarrow \underset{3\ 6}{3\,CO_2} \quad + \underset{8\ 4}{4H_2O}$$

Balance the equation.

Convert Reactant #1 to moles of Product #1.

$$1.0\text{ mol } C_3H_8 \times \frac{3\text{ mol } CO_2}{1\text{ mol } C_3H_8} = 3.0\text{ mol } CO_2$$

Convert Reactant #2 to moles of Product #1.

$$2.0\text{ mol } O_2 \times \frac{3\text{ mol } CO_2}{5\text{ mol } O_2} = 1.2\text{ mol } CO_2$$

Limiting Reactant = O_2 *Excess Reactant* = C_3H_8

How many moles of CO_2 would be produced? 1.2 mol CO_2

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:

$$2\,C_4H_{10} + 13\,O_2 \rightarrow 8\,CO_2 + 10\,H_2O$$

16 10

Balance the equation.

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

$$16.78\text{ g } C_4H_{10} \times \frac{1\text{ mol } C_4H_{10}}{58.122\text{ g } C_4H_{10}} \times \frac{8\text{ mol } CO_2}{2\text{ mol } C_4H_{10}} = 1.155\text{ mol } CO_2$$

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

$$32.0\text{ g } O_2 \times \frac{1\text{ mol } O_2}{32.00\text{ g } O_2} \times \frac{8\text{ mol } CO_2}{13\text{ mol } O_2} = 0.615\text{ mol } CO_2$$

Limiting Reactant = O_2 *Excess Reactant =* C_4H_{10}

How many GRAMS of CO_2 would be produced?

$$0.615\text{ mol } CO_2 \times \frac{44.01\text{ g } CO_2}{1\text{ mol } CO_2} = 27.1\text{ g } CO_2$$

Example #8

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

$$2\,K + 2\,H_2O \rightarrow 2\,KOH + 1\,H_2$$

2

Balance the equation.

Limiting reactant = K.

Determine the limiting reactant.

$$4.0\text{ g K} \times \frac{1\text{ mol K}}{39\text{ g K}} \times \frac{2\text{ mol KOH}}{2\text{ mol K}} = 0.10\text{ mol KOH}$$

$$100.\text{ g } H_2O \times \frac{1\text{ mol } H_2O}{18.0\text{ g } H_2O} \times \frac{2\text{ mol KOH}}{2\text{ mol } H_2O} = 5.56\text{ mol KOH}$$

What is the excess reactant? H_2O

How many GRAMS of KOH would be produced?

$$0.10\text{ mol KOH} \times \frac{56.1\text{ g KOH}}{1\text{ mol KOH}} = 5.6\text{ g KOH}$$

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?

$$2\,\text{Cu} + 1\,\text{O}_2 \rightarrow 2\text{CuO}$$

$$16.0\text{ g Cu} \times \frac{1\text{ mol Cu}}{63.55\text{ g Cu}} \times \frac{2\text{ mol CuO}}{2\text{ mol Cu}} = 0.252\text{ mol CuO}$$

$$20.0\text{ g O}_2 \times \frac{1\text{ mol O}_2}{32.00\text{ g O}_2} \times \frac{2\text{ mol CuO}}{1\text{ mol O}_2} = 1.25\text{ mol CuO}$$

$$0.252\text{ mol CuO} \times \frac{79.55\text{ g CuO}}{1\text{ mol CuO}} = \underline{20.0\text{ g CuO}}$$

Example #10

How many grams of AlBr₃ can be produced when 35 grams of Al react with 45 grams of Br_2?

$$2\,\text{Al} + 3\,\text{Br}_2 \rightarrow 2\text{AlBr}_3$$

$$35\text{ g Al} \times \frac{1\text{ mol Al}}{27.0\text{ g Al}} \times \frac{2\text{ mol AlBr}_3}{2\text{ mol Al}} = 1.3\text{ mol AlBr}_3$$

$$45\text{ g Br}_2 \times \frac{1\text{ mol Br}}{160.0\text{ g Br}_2} \times \frac{2\text{ mol AlBr}_3}{3\text{ mol Br}_2} = 0.19\text{ mol AlBr}_3$$

$$0.19\text{ mol AlBr}_3 \times \frac{267\text{ g AlBr}_3}{1\text{ mol AlBr}_3} = 50.73\text{ g AlBr}_3$$

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?

$$2\,\text{LiOH} + 1\,\text{CO}_2 \rightarrow 1\,\text{Li}_2\text{CO}_3 + 1\,\text{H}_2\text{O}$$

$$0.209\text{ mol Li}_2\text{CO}_3 \times \frac{73.89\text{ g Li}_2\text{CO}_3}{\text{mol Li}_2\text{CO}_3} = \boxed{15.4\text{ g Li}_2\text{CO}_3}$$

$$10.0\text{ g LiOH} \times \frac{1\text{ mol LiOH}}{23.95\text{ g LiOH}} \times \frac{1\text{ mol Li}_2\text{CO}_3}{2\text{ mol LiOH}} = 0.209\text{ mol Li}_2\text{CO}_3$$

$$50.0\text{ g CO}_2 \times \frac{1\text{ mol CO}_2}{44.01\text{ g CO}_2} \times \frac{1\text{ mol Li}_2\text{CO}_3}{1\text{ mol CO}_2} = 1.14\text{ mol Li}_2\text{CO}_3$$

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:

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

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.

$$1\,CS_2 + 3\,O_2 \rightarrow 1\,CO_2 + \underset{4}{2}\,SO_2$$

Balance the equation.

Determine the limiting reactant.

$$1.0\text{ mol }CS_2 \times \frac{1\text{ mol }CO_2}{1\text{ mol }CS_2} = 1.0\text{ mol }CO_2$$

limiting reactant: O_2

$$1.0\text{ mol }O_2 \times \frac{1\text{ mol }CO_2}{3\text{ mol }O_2} = 0.3\text{ mol }CO_2$$

Determine the MOLES USED of excess reactant.

$$1.0\text{ mol }O_2 \times \frac{1\text{ mol }CS_2}{3\text{ mol }O_2} = 0.3\text{ mol }CS_2$$

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

$$1.0\text{ mol }CS_2 - 0.3\text{ mol }CS_2 = 0.7\text{ mol }CS_2$$

Date:

2b. Excess Reactants (cont.)

Example #2

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

$2\,Al + 3\,Br_2 \rightarrow 2\,AlBr_3$

Balance the equation.

Determine the limiting reactant. Limiting reactant: Br_2

$15.0\,g\,Al \times \frac{1\,mol\,Al}{26.98\,g\,Al} \times \frac{2\,mol\,AlBr_3}{2\,mol\,Al} = 0.556\,mol\,AlBr_3$

$8.0\,g\,Br_2 \times \frac{1\,mol\,Br_2}{160\,g\,Br_2} \times \frac{2\,mol\,AlBr_3}{3\,mol\,Br_2} = 0.03\,mol\,AlBr_3$

Determine the GRAMS USED of excess reactant.

$0.05\,mol\,Br_2 \times \frac{2\,mol\,Al}{3\,mol\,Br_2} \times \frac{27.0\,g\,Al}{1\,mol\,Al} = 0.90\,g\,Al$

Calculate the remaining mass of excess reactant.

$15.0\,g\,Al - 0.9\,g\,Al = 14.1\,g\,Al$

Example #3

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

$1\,I_2 + 1\,Cl_2 \rightarrow 2\,ICl$

Balance the equation.

Determine the limiting reactant. limiting reactant: I_2

0.39 mol $100.\,g\,I_2 \times \frac{1\,mol\,I_2}{253.8\,g\,I_2} \times \frac{2\,mol\,ICl}{1\,mol\,I_2} = 0.788\,mol\,ICl$

$50.0\,g\,Cl_2 \times \frac{1\,mol\,Cl_2}{70.90\,g\,Cl_2} \times \frac{2\,mol\,ICl}{1\,mol\,Cl_2} = 1.41\,mol\,ICl$

Determine the GRAMS USED of excess reactant.

$0.39\,mol\,I_2 \times \frac{1\,mol\,Cl_2}{1\,mol\,I_2} \times \frac{70.9\,g\,Cl_2}{1\,mol\,Cl_2} = 28\,g\,Cl_2$

Calculate the remaining mass of excess reactant.

$50.0\,g\,Cl_2 - 28.0\,g\,Cl_2 = 22.0\,g\,Cl_2$

Date:

3. Percent Yield

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

Terms:

Experimental (Actual) Yield – The amount of product you actually produce.

Theoretical Yield – The amount of product you could produce.

PERCENT YIELD

$$\frac{\text{Actual Yeild}}{\text{Theoretical Yeild}} \times 100\%$$

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?

$$PY = \frac{10.23\,g\,AgCl}{10.81\,g\,AgCl} \times 100\% = 94.63\%$$

3. A chemist needs to create 5.00 grams $\overset{H_2S}{\text{hydrogen}}$ sulfide. If the reaction she is using only has a 77% yield, how many grams should she theoretically plan on producing?

$$5.00\,g\,H_2S \times \frac{100\,g\,H_2S}{77\,g\,H_2S} = 6.49\,g\,H_2S$$

Date:

REVIEW

Flowchart:	
Basic Stoichiometry Problems Data is given about only 1 reactant; the others are assumed to be in excess.	**Limiting Reactant Problems** 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?

$$5.00 g Fe \times \frac{1 mol Fe}{55.85 g Fe} \times \frac{2 mol Fe_2O_3}{4 mol Fe} = 0.045 mol Fe_2O_3$$

$$100. g O_2 \times \frac{1 mol O_2}{32.09 O_2} \times \frac{2 mol Fe_2O_3}{3 mol O_2} = 2.08 mol Fe_2O_3$$

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

$$0.045 mol Fe_2O_3 \times \frac{159.7 g Fe_2O_3}{1 mol Fe_2O_3} = 7.19 g Fe_2O_3$$

3. What is the excess reactant? O_2 How many grams of it remain?

$$0.067 mol O_2 \times \frac{32.00 g O_2}{1 mol O_2} = 2.14 g$$

$$5.00 g Fe \times \frac{1 mol Fe}{55.85 g Fe} \times \frac{3 mol O_2}{4 mol Fe} = 0.067 mol O_2$$

$$\boxed{97.9 g O_2}$$

4. If only 4.7 grams of $\overset{Fe_2O_3}{\text{ferric}}$ $\overset{O^{2-}}{\text{oxide}}$ are collected, what is the percent yield?

$$PY = \frac{4.7 g Fe_2O_3}{7.19 g Fe_2O_3} \times 100\% = 65.4 \%$$