2/7 or 2/10 STOICHIOMETRY

Stoichiometry deals with the mass relationship among the reactants and products in a chemical reaction. Stoichiometry allows us to predict how much reactant we need to produce a certain amount of product or how much product we can expect to get out of a certain reaction based upon how much reactant we use.

Mole Ratios

The central step in any stoichiometric calculation is the mole ratio. A mole ratio is a conversion factor that allows us to convert from a given amount of reactant or product to the desired quantity. Mole ratios are derived from balanced chemical equations.

Consider, for example, the chemical equation for the electrolysis of aluminum oxide to produce aluminum and oxygen.

$$2Al_2O_{3(l)} \longrightarrow 4Al_{(s)} + 3O_{2(g)}$$

The following mole ratios can be written for the reaction above:

$$\frac{2 \text{ mol } Al_2O_3}{4 \text{ mol Al}} \quad \text{or} \quad \frac{4 \text{ mol Al}}{2 \text{ mol } Al_2O_3} \quad \text{or} \quad \frac{4 \text{ mol Al}}{3 \text{ mol } O_2}$$

$$\frac{3 \text{ mol } O_2}{4 \text{ mol Al}} \quad \text{or} \quad \frac{2 \text{ mol } Al_2O_3}{3 \text{ mol } O_2} \quad \text{or} \quad \frac{3 \text{ mol } O_2}{2 \text{ mol } Al_2O_3}$$

Example 1: Write all of the possible mole ratios for the reaction below:

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)}$$

N-1

Problem type #1: 2/7 or 2/10

Mole-Mole Calculations (*Given* and *unknown* quantities are amounts in moles)

In a mole-mole calculation, you will calculate the number of moles of one substance that will react with or be produced from a given number of moles of another substance. This requires one step: a conversion using a mole-mole ratio.

Example 2: How many moles of oxygen are produced when 3.2 moles of potassium chlorate decomposes? The other product is potassium chloride.

Example 3: Given: $2NH_4NO_3 \longrightarrow 2N_2 + 4H_2O + O_2$

How many moles of water are produced if 15.0 moles of oxygen are produced in the above reaction?

Problem type #2: 2/11 or 2/12

Mole-Mass Calculations (*Given* is an amount in moles and the *unknown* is a mass that is often expressed in grams.)

In a mole-mass calculation, you will calculate the mass of one substance that will react with or be produced from a given number of moles of another substance. This requires two steps: 1) Convert from what you are given to what you are looking for using a mole - mole ratio. 2) Convert from moles of what you are looking for to grams using molar mass. These two steps are done using one factor-label set-up.

Example 4: Given: $N_2 + 3H_2 \longrightarrow 2NH_3$

What mass of nitrogen is required to produce 35.0 moles of ammonia?

N-2

2/11 or 2/12

Example 5: Hydrazine, N_2H_4, is used as a rocket fuel. Reacting with oxygen, it produces nitrogen and water. What mass of oxygen is needed to burn 100.0 moles of hydrazine?

Problem type #3:

Mass-Mole Calculations (*Given* is a mass in grams and the *unknown* is an amount in moles.)

In a mass-mole calculation, you will calculate the number of moles of one substance that will react with or be produced from a given mass of another substance. This requires two steps: 1) Convert from grams of what you are given to moles using molar mass. 2) Convert from moles of what you are given to moles of what you are looking for using a mole-mole ratio. This calculation is also done in one factor-label set-up.

Example 6: Given: $2Na + 2H_20 \longrightarrow 2NaOH + H_2$

How many moles of hydrogen gas are produced if 56.7 g of Na are added to water?

Example 7: Given: $4Fe + 3O_2 \longrightarrow 2Fe_2O_3$

How many moles of iron are needed to produce 250.0 g of iron (III) oxide?

- Problem type #4: 2/17 or 2/18

Mass-Mass Calculations (*Given* is a mass in grams and the *unknown* is a mass in grams.)

In a mass-mass calculation, you will calculate the mass of one substance that will react with or be produced from a given mass of another substance. This will require three steps: 1) Convert grams of what you are given to moles using molar mass. 2) Convert from moles of what you are given to moles of what you are looking for using a mole-mole ratio. 3) Convert from moles of what you are looking for to grams using molar mass. These steps can be carried out using one factor-label set-up.

Example 8: What mass of oxygen is needed to completely burn 137.9 g of butane (C_4H_{10})?

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

Example 9: Water decomposes with electricity to produce hydrogen and oxygen gas. How many grams of hydrogen can be produced if 75.0 g of water decomposes?

Limiting Reactants 2/13 or 2/14

Limiting Reactant Vocabulary

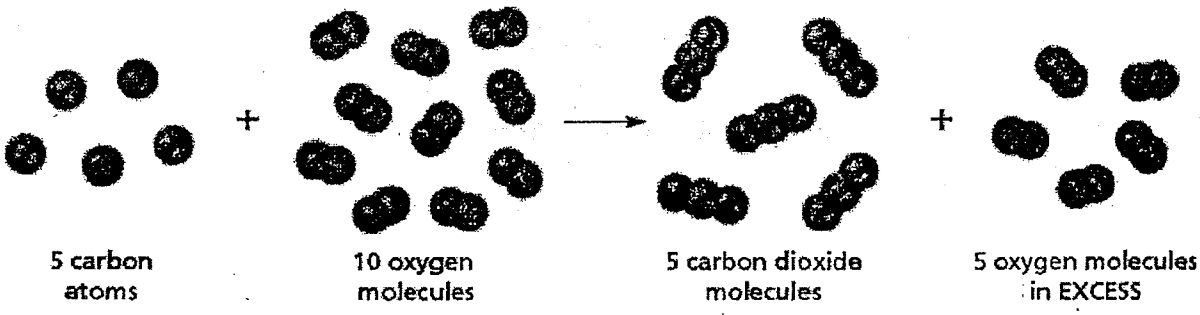
1) limiting reactant - the reactant that limits the amount of product produced by a chemical reaction. This is the reactant that will be completely consumed during the reaction. When the limiting reactant "runs out" the reaction will stop and no more product will be formed.

2) excess reactant - this is the "other" reactant that does not get completely consumed during a reaction.

Consider the reaction between carbon and oxygen to form carbon dioxide.

$$C(s) + O_2(g) \longrightarrow CO_2(g)$$

According to the equation, one mole of carbon reacts with one mole of oxygen to form one mole of carbon dioxide. Suppose you could mix 5 mol of C with 10 mol of O_2 and allow the reaction to take place. The diagram below shows that there is more oxygen than is needed to react with the carbon. Carbon is the limiting reactant in this situation, and it limits the amount of CO_2 that is formed. Oxygen is the excess reactant, and 5 l of O_2 will be left over at the end of the reaction.



NOTE: When two amounts of reactants are given in a stoichiometry problem, it must be treated as a limiting reactant problem. You must determine which reactant is "limiting" and use this quantity for all subsequent calculations! At the end of a reaction involving a limiting reactant, the reaction mixture will be composed of the product(s) and the excess reagent. The limiting reagent is completely consumed. The following examples will show you how to handle a stoichiometry problem involving a limiting reactant.

2/13 or 2/14

Example 10: Given: $2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$

a) If 3.2 moles of Al react with 10.1 moles of HCl, which reactant is limiting?

b) How many moles H_2 are formed?

c) How many mole of excess reagent remain after the reaction?

Example 11: Given: $N_2 + 3H_2 \longrightarrow 2NH_3$

a) If 64.3 g of N_2 react with 16.5 g of H_2, identify the limiting reactant.

b) How many grams of NH_3 will be produced?

c) How many grams of excess reagent remain after the reaction?

2/18 or 2/14

Example 12: Given: $Ca(OH)_2 + 2HCl \longrightarrow CaCl_2 + 2H_2O$

If 110.0 g of $Ca(OH)_2$ react with 96.6 g of HCl, how many grams of each product will form and how many grams of excess reagent remain after the reaction stops?

PERCENT YIELD VOCABULARY

1) theoretical yield -the maximum amount of product that can be produced from a iven amount of reactant.

2) actual yield -the measured amount of product obtained from a reaction.

3) Percent yield -

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

Example 13: Methanol can be produced through the reaction of CO and H2 in the presence of a catalyst:

$$CO(g) + 2H_2(g) \xrightarrow{\text{catalyst}} CH_3OH(l)$$

If 75.0g of CO reacts to produce 68.4g of CH_3OH, what is the percent yield of CH_3OH?

2/13 or 2/14

PRACTICE PROBLEMS

1) Given: $N_2 + 3H_2 \longrightarrow 2NH_3$

If 5.50g of hydrogen react with excess nitrogen to produce 20.4g of ammonia, what is the percent yield?

2) Given: $3NaBH_4 + 4BF_3 \longrightarrow 3NaBF_4 + 2B_2H_6$

If you begin with 18.9g of $NaBH_4$ and excess BF_3, and you isolate 7.50g of B_2H_6, what is the percent yield of B_2H_6?

3) Given: $SiO_2 + 4HF \longrightarrow SiF_4 + 2H_2O$

Calculate the percent yield if 1.28g of SiO_2 gives 1.08g of SiF_4 as product.

2/7 or 2/10

Stoichiometry (Mole Relationships)

Chemical reactions are like recipies - two of these, one of those make 4 servings - and so on. If you want the recipie to come out right you need start with the right ratio of ingredients. You can make a bigger or smaller recipie, but you have to keep the *ratios* the same. Otherwise, you'll get a gloppy cake or a sour cookie. As you work through the following questions, keep the idea of a recipie in mind.

Balance the following reaction:

$$N_{2\,(g)} \quad + \quad H_{2\,(g)} \quad \text{---------}> \quad NH_{3\,(g)}$$

Using conversions, fill in the following table:

Situation	N_2	H_2	NH_3	Ratio of all three
For a single "recipie" how many molecules would you need or make?				
If you made the "recipie" one hundred times, how many molecules would you need or make?				
If you made the "recipie" 538 times, how many molecules would you need or make?				
If you made the "recipie" a mole number of times, how many molecules would you need or make?				
Since its hard to count molecules, how many moles of each would you need or make for the previous situation?				
Since these are all gases, it may be easier to use volumes to measure out ingredients?				
Or, maybe we could use masses to find how much we need or will make?				

What did you find to be true about the mole ratios in your table? Do they always hold true? Explain mathematically why or why not. Compare them to the coefficients in your equation.

As you saw in the previous exercise, we can use the mole ratios of a balanced equation to predict how much reactant we will need (like making a grocery list for a party), or how much product we can make (when you can't go to the store, what is the maximum amount you can cook).

2/7 or 2/10
2/11 or 2/12

Name: _____

STOICHIOMETRY WORKSHEET #1
MOLE-MOLE CALCULATIONS

Sample Problems:

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

1. In the reaction above, if 0.5 moles of Al reacts,

   a. How many moles of H_2 are produced? b. How many moles of HCl are needed?

$4Fe + 3\ O2 \rightarrow 2Fe_2O_3$

2. In the above reaction, if 0.75 moles of Fe reacts,

   a. How many moles of O_2 are needed? b. How many moles of Fe_2O_3 are produced?

   c. How many grams of Fe_2O_3 is this?

   d. If 10.0 grams of Fe react, how many moles of O_2 will be needed?

Homework Problems:

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

3. In the above reaction, if 0.75 moles of C_2H_4 reacts,

   a. How many moles of CO_2 are produced? b. How many moles of O_2 are also needed?

P-2

See pg N-1 and N-2 for help

2/7 or 2/10
2/11 or 2/12

$2H_3PO_4 + 3Mg(OH)_2 \rightarrow Mg_3(PO_4)_2 + 6H_2O$

4. In the above reaction, if 0.42 moles of $Mg(OH)_2$ reacts,

a. How many moles of H_3PO_4 react? b. How many moles of water are formed?

c. How many moles of $Mg_3(PO_4)_2$ are made? d. How many grams of $Mg_3(PO_4)_2$ is this?

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

5. In the above reaction, if 2.3 moles of Al_2O_3 are produced,

a. How many moles of O_2 are needed? b. How many moles of Al are needed?

c. How many grams of Al is this?

d. if 5.0 g grams of Al react, how many moles of O_2 are needed?

$Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2\ Ag$

6. In the above reaction, if 0.15 moles of $AgNO_3$ reacts,

a. How mnay moles of copper will react? b. How many moles of silver will there be?

c. How many grams of silver is this?

d. if 15.0 grams of copper reacts, how many moles of silver will be produced?

P-3

See pg. N-1 and N-2 for help

2/11 or 2/12

Stoichiometry: Moles to Grams

$2\ Na + Cl_2 \rightarrow 2\ NaCl$

1. How many moles of NaCl are produced from 36 g of Cl_2?

2. How many grams of Na are needed to produce 2.6 mol of NaCl?

$Fe_2O_3 + 3\ CO \rightarrow 2Fe + 3\ CO_2$

3. How many grams of iron are produced from 1.5 mol of Fe_2O_3?

4. How many moles of CO are needed to produce 4.5 g of CO_2?

P-4

See pg N-2 & N-3 for help

2/11 or 2/12

STOICHIOMETRY PRACTICE- Balance Equations First!

___H_2 + __O_2 ---> __H_2O

How many grams of H_2O are produced when 2.50 moles of oxygen are used?

If 3.00 moles of H_2O are produced, how many grams of oxygen must be consumed?

___ $KClO_3$ ---> ___ KCl + ___O_2

How many moles of O_2 can be produced by letting 12.00 moles of $KClO_3$ react?

__ K + __Cl_2 ---> __KCl

How many moles of KCl are produced from 2.50 g of K and excess Cl_2.

How many grams of KCl are produced from 1.00 mol of Cl_2 and excess K?

___Na_2O + __H_2O ---> __ NaOH

How many moles of NaOH are produced from 469 grams of Na_2O?

How many grams of Na_2O are required to produce 15.3 moles of NaOH?

P-5

See pg. N-2 and N-3 for help

2/17 or 2/18

Name: _____

STOICHIOMETRY WORKSHEET #2
MASS-MASS CALCULATIONS

Sample Problems:

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

1. In the reaction above, if 26.0 grams of O_2 reacts, calculate

   a. The mass of Fe that reacts

   b. The mass of Fe_2O_3 produced

2. In the reaction **$2KClO_3 \rightarrow 2KCl + 3O_2$**

If 2.74 grams of KCl are produced, calculate:

   a. The mass of O_2 produced

   b. the mass of $KClO_3$ that reacts

Homework Problems:

$Al_2(SO_4)_3 + 6NaOH \rightarrow 2Al(OH)_3 + 3\ Na_2SO_4$

3. In the above reaction, if 22.7 grams of NaOH reacts, calculate

   a. The mass of $Al_2(SO_4)_3$ that reacts

   b. The mass of aluminum hydroxide produced

   c. The mass of sodium sulfate produced

P-6

See pg. N-4 for help

2/17 or 2/18

$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

4. In the above reaction, if 109.0 grams of pentane reacts, calculate:

a. The mass of O2 that reacts

b. The mass of carbon dioxide produced

c. The mass of water produced

$P_4 + 5O_2 \rightarrow P_4O_{10}$

5. In the above reaction, if 7.75 grams of P_4 reacts, calculate:

a. the mass of tetraphosphorus decoxide that is produced

b. The mass of O_2 that reacts

$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2NO_2 + 2H_2O$

If 11.3 g grams of NO_2 react, calculate:

a. The mass of nitric acid that reacts

b. The mass of copper that reacts

c. The mass of copper (II) nitrate that is produced

d. The mass of water that is produced

See pg. N-4 for help

2/17 or 2/18

Name: _____

Percent Yield

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

actual yield – experimental value

theoretical yield – calculated value

$$SO_3 + H_2O \rightarrow H_2SO_4$$

1. Calculate the percent yield if 500. g of sulfur trioxide reacts with excess water to produce 575 g of sulfuric acid.

$$Cl_2 + 2\ KBr \rightarrow 2\ KCl + Br_2$$

2. Calculate the percent yield if 200. g of chlorine reacts with excess potassium bromide to produce 410. g of bromine.

$$CH_4 + 2\ O_2 \rightarrow 2\ H_2O + CO_2$$

3. Calculate the percent yield of carbon dioxide if 1000. g of methane reacts with excess oxygen to produce 2300. g of carbon dioxide.

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

4. Calculate the percent yield of $MgCl_2$ if 100. g of Mg reacts with excess HCl to yield 330. g of $MgCl_2$.

P-8

See pg. N-7 for help