General Stoichiometry Notes

STOICHIOMETRY: tells relative amts of reactants & products in a chemical reaction

- Given an amount of a substance involved in a chemical reaction, we can figure out the amount of the other substances are needed or produced
- Always compare the number of MOLES
- $\underline{4}\ Fe + \underline{3}\ O_2 \rightarrow \underline{2}\ Fe_2O_3$
- If I have 4 moles of Fe, I need 3 moles of O_2 in order to produce 2 moles of Fe_2O_3.
- Comparison of coefficients = MOLE RATIO
- In the above eqn, what is the mole ratio between Fe_2O_3 and O_2?
- Use coefficients… 2 : 3 or 2 to 3

To solve stoichiometry problems… ALWAYS!!!!!!!!!!!

**** WRITE THE BALANCED EQN & GIVEN AND UNKNOWN INFORMATION! ****

If given…	**Asked for/unknown…**	**Use step(s)**
Moles	moles	**2**
Moles	grams or molecules	**2** & **3**
Grams or molecules	moles	**1** & **2**
Grams or molecules	grams or molecules	**1**, **2**, & **3**

1.) Find moles of given element or compound. (Set up a "T chart".)

# and unit given in problem	**1 mole**	**= answer to step 1**
	***#* unit given**	

*** if unit given is grams, the *#* used should be molar mass from P.T.**

*** if unit given is molecules, the *#* used should be 6.022 x 10^{23}**

2.) Use mole ratio (coefficients) from balanced equation. (Set up below.)

$$\frac{\#\text{ moles given substance}}{\text{coefficient of given subst.}} = \frac{x\text{ moles unknown substance}}{\text{coefficient of unknown subst.}}$$

Then, solve for x.

 # should be your answer from step 1 or the number of moles given in the problem

3.) Find answer. (Set up a "T chart".)

x moles unknown subst	**(#) unknown unit**	**= final answer**
	1 mole	

"x" should be your answer from step 2

If the unknown unit is grams, the (#) should be molar mass from PT

If the unknown unit is molecules, the (#) should be 6.022 x 10^{23}

EXAMPLE 1:

How many moles of ammonia (NH_3) can be produced by the complete reaction of 3.25 moles of hydrogen?

$$N_2 + \underset{3.25\text{ moles}}{\underline{3}\,H_2} \rightarrow \underset{?\text{ moles}}{\underline{2}\,NH_3}$$

given moles, asked for moles - only need to use step **2**

2.) $\frac{3.25 \text{ moles } H_2}{3} = \frac{x \text{ moles } NH_3}{2}$

$3x = 6.5$

$x =$ **2.17 moles NH_3**

EXAMPLE 2:

What mass of NaOH are needed to react completely with 6.21 moles of $Ca(OH)_2$?

$$Na_2CO_3 + \underset{6.21\text{ moles}}{Ca(OH)_2} \rightarrow \underset{?\text{ g}}{\underline{2}\,NaOH} + CaCO_3$$

given moles, asked for grams - needs steps **2** & **3**

2.) $\frac{6.21 \text{ moles } Ca(OH)_2}{1} = \frac{x \text{ moles NaOH}}{2}$

$x = 12.42$ moles NaOH

3.) $\underline{6.21 \text{ moles NaOH}} \left| \frac{40.0 \text{ grams}}{1 \text{ mole}} \right. =$ **497 g NaOH**

Na: 2 x 23.0 = 46.0
C: 1 x 12.0 = 12.0
O: 3 x 16.0 = 48.0 +
106.0

EXAMPLE 3:

If 34.32 grams of acetylene (C_2H_2) are burned in air, how many moles of CO_2 can be formed?

$$\underset{34.32\text{ g}}{\underline{2}\;C_2H_2} + \underline{5}\;O_2 \rightarrow \underset{?\text{ moles}}{\underline{4}\;CO_2} + \underline{2}\;H_2O$$

given grams, asked for moles need steps **1** & **2**

1.) $\underline{34.32 \text{ g } C_2H_2} \left| \frac{1 \text{ mole } C_2H_2}{26.0 \text{ grams}} \right. = 1.32 \text{ moles } C_2H_2$

C: 2 x 12.0 = 24.0
H: 2 x 1.0 = 2.0 +
26.0

2.) $\frac{1.32 \text{ moles } C_2H_2}{2} = \frac{x \text{ moles } CO_2}{4}$

$2x = 5.28$

$x =$ **2.64 moles CO_2**

EXAMPLE 4:

If 27.8 grams of Na_2SO_4 are reacted with excess $Al_2(CO_3)_3$, how many grams of $Al_2(SO_4)_3$ will be formed?

$$\underset{27.8\text{ g}}{\underline{3}\;Na_2SO_4} + Al_2(CO_3)_3 \rightarrow \underset{?\text{ g}}{Al_2(SO_4)_3} + \underline{3}\;Na_2CO_3$$

given grams, asked for grams - need steps **1**, **2**, & **3**

1.) $\underline{27.8 \text{ g } Na_2SO_4} \left| \frac{1 \text{ mole } Na_2SO_4}{142.1 \text{ grams}} \right. = 0.196 \text{ moles } Na_2SO_4$

Na: 2 x 23.0 = 46.0
S: 1 x 32.1 = 32.1
O: 4 x 16.0 = 64.0 +
142.1

2.) $\frac{0.196 \text{ moles } Na_2SO_4}{3} = \frac{x \text{ mole } Al_2(SO_4)_3}{1}$

$3x = 0.196$

$x = 0.0653$ moles $Al_2(SO_4)_3$

3.) $\frac{0.0653 \text{ mole } Al_2(SO_4)_3}{} \Big| \frac{342.3 \text{ g } Al_2(SO_4)_3}{1 \text{ mole } Al_2(SO_4)_3} =$ **22.4 g $Al_2(SO_4)_3$**

Al: 2 x 27.0 = 54.0
S: 3 x 32.1 = 96.3
O: 12 x 16.0 = 192.0 +
342.3

EXAMPLE 5:

How many molecules of oxygen gas are required to completely react with 85.0 grams of propane (C_3H_8)?

$C_3H_8 + \underline{5}\ O_2 \rightarrow \underline{3}\ CO_2 + \underline{4}\ H_2O$

85.0 g ? mcs

given grams, asked for mcs - need steps **1**, **2**, & **3**

1.) $\frac{85.0 \text{ g } C_3H_8}{} \Big| \frac{1 \text{ mole}}{44.0 \text{ g}} = 1.93$ moles C_3H_8

C: 3 x 12.0 = 36.0
H: 8 x 1.0 = 8.0 +
44.0

2.) $\frac{1.93 \text{ moles } C_3H_8}{1} = \frac{x \text{ moles } O_2}{5}$

$x = 9.65$ moles O_2

3.) $\frac{9.65 \text{ moles}}{} \Big| \frac{6.022 \times 10^{23} \text{ mcs}}{1 \text{ mole}} =$ **5.81×10^{24} mcs O_2**

Practice Problem:

How many grams of calcium nitrate are formed when 57.9 grams of iron (III) nitrate react with excess calcium hydroxide according to the following equation?

___ $Ca(OH)_2$ + ___ $Fe(NO_3)_3$ → ___ $Ca(NO_3)_2$ + ___ $Fe(OH)_3$

Stoichiometry Problems 1 Worksheet

1. When lead (II) sulfide is burned in air, lead (II) oxide and sulfur dioxide are produced. If 0.890 moles of sulfur dioxide were produced, how many moles of oxygen gas were required to react with the lead (II) sulfide? ___ PbS + ___ O_2 → ___ PbO + ___ SO_2

2. In the synthesis reaction of aluminum and oxygen to produce aluminum oxide, how many grams of aluminum are required to react with 0.223 moles of oxygen?
   ___ Al + ___ O_2 → ___ Al_2O_3

3. Calculate the number of grams of oxygen produced if 2.50 grams of potassium chlorate are decomposed completely by heating.
   ___ $KClO_3$ → ___ KCl + ___ O_2

4. How many moles of oxygen are needed for the complete combustion of 3.0 moles of methane (CH_4)? ___ CH_4 + ___ O_2 → ___ CO_2 + ___ H_2O

5. Using the same equation from #4, how many grams of carbon dioxide are formed when 8.0 grams of methane react? ___ CH_4 + ___ O_2 → ___ CO_2 + ___ H_2O

6. When elemental sulfur combines with oxygen gas, sulfur dioxide is formed. What is the total number of grams of oxygen needed to react completely with 2.0 moles of sulfur?
   ___ S + ___ O_2 → ___ SO_2

7. In the synthesis of water from its elements, what is the total number of grams of oxygen gas needed to produce 54 grams of water? ___ H_2 + ___ O_2 → ___ H_2O

8. How many moles of aluminum oxide will be formed when 27 grams of aluminum react completely with excess oxygen gas? ___ Al + ___ O_2 → ___ Al_2O_3

9. What mass (in grams) of sodium oxide is produced by the reaction of 1.44 grams of sodium with excess oxygen? __ Na + __ O_2 → __ Na_2O

10. What mass (in grams) of water will be given off when 1.92×10^{22} molecules of octane (C_8H_{18}) are burned completely in air? __ C_8H_{18} + __ O_2 → __ CO_2 + __ H_2O

11. How many grams of $Al_2(SO_4)_3$ are need to react with KCl in order to produce 1.245 moles of K_2SO_4?

__ $Al_2(SO_4)_3$ + __ KCl → __ $AlCl_3$ + __ K_2SO_4

12. Hydrogen gas can be produced through the following unbalanced reaction.

__ Mg + __ HCl → __ $MgCl_2$ + __ H_2

(A) What mass of HCl is consumed by the reaction of 2.50 moles of magnesium?

(B) What mass of each product is produced in part (A)?

13. Acetylene gas, C_2H_2, used in welding, produces an extremely hot flame when it burns in pure oxygen according to the following unbalanced reaction.

__ C_2H_2 + __ O_2 → __ CO_2 + __ H_2O

How many molecules of CO_2 are produced when 2.50×10^4 grams of C_2H_2 burn completely?

PERCENT YIELD NOTES

~ compares the actual amount of product that you made (in an experiment) to the amount of product you should have made (according to calculations)

~ ACTUAL YIELD: amount of product that you made in an experiment; when given in the problem, the amount (grams, atoms/molecules, moles) given will be associated with a product of the reaction

~ THEORETICAL YIELD: amount of product that you should have made (according to calculations); amount given with a reactant should be used to calculate theoretical yield

~ $$\%\ \text{YIELD} = \frac{\text{ACTUAL YIELD}}{\text{THEORETICAL YIELD}}\ \text{X}\ 100$$

EXAMPLE

(A) What is the theoretical yield of carbon dioxide if 9.5 grams of aluminum bicarbonate are completely decomposed?

(B) If a student makes 5.2 grams of CO_2 in an experiment, what is the % yield?

$$\_\_\_\ Al(HCO_3)_3 \rightarrow \_\_\_\ Al_2O_3 + \_\_\_\ CO_2 + \_\_\_\ H_2O$$

ANSWER (A):

$$\underline{\ 2\ }\ \underset{9.5\ \text{g}}{Al(HCO_3)_3} \rightarrow \_\_\_\ Al_2O_3 + \underline{\ 6\ }\ \underset{?\ \text{g}}{CO_2} + \underline{\ 3\ }\ H_2O$$

1.) $$\left.\frac{9.5\ \text{g}\ Al(HCO_3)_3}{}\right|\frac{1\ \text{mole}\ Al(HCO_3)_3}{210\ \text{grams}} = 0.0452\ \text{moles}\ Al(HCO_3)_3$$

2.) $$\frac{0.0452\ \text{moles}\ Al(HCO_3)_3}{2} = \frac{x\ \text{moles}\ CO_2}{6} \qquad 2x = 0.2712$$

$$x = 0.1356\ \text{moles}\ CO_2$$

3.) $$\left.\frac{0.1356\ \text{moles}\ CO_2}{}\right|\frac{44.0\ \text{g}\ CO_2}{1\ \text{mole}} = \mathbf{6.0\ g\ CO_2}$$ is the theoretical yield.

ANSWER (B):

% yield = $\frac{5.2\ \text{g}}{6.0\ \text{g}}$ x 100 = **87 %**

PRACTICE PROBLEM

(A) What is the theoretical yield of water if 7.5 grams of oxygen are reacted with excess hydrogen?

(B) If a student produces 7.2 grams of water, what is the student's % yield?

$$\_\_\_\ H_2 + \_\_\_\ O_2 \rightarrow \_\_\_\ H_2O$$

PERCENT YIELD WORKSHEET

1.) Use the following information to answer the questions. In the following reaction, 41.0 grams of lead (II) chloride are reacted with excess sodium chromate.

___ $PbCl_2$ + ___ Na_2CrO_4 → ___ $PbCrO_4$ + ___ $NaCl$

(A) What is the theoretical yield (in grams) of sodium chloride in this reaction?

(B) If a student performed this experiment and recovered 16.5 grams of sodium chloride, what is the student's percent yield?

2.) Use the following information to answer the questions. In the following reaction, 1.70 moles of zinc nitrate are reacted with excess chromium (II) phosphide.

___ $Zn(NO_3)_2$ + ___ Cr_3P_2 → ___ Zn_3P_2 + ___ $Cr(NO_3)_2$

(A) What is the theoretical yield (in grams) of zinc phosphide?

(B) If a student performed this experiment and recovered 149 grams of zinc phosphide, what is the student's percent yield?

3.) Use the following information to answer the questions. In the following reaction, 10.0 grams of copper (II) sulfate are reacted with excess iron (III) phosphate.

___ $CuSO_4$ + ___ $FePO_4$ → ___ $Cu_3(PO_4)_2$ + ___ $Fe_2(SO_4)_3$

(A) How many grams of copper (II) phosphate can be produced?

(B) If a student performed this experiment and recovered 6.70 grams of copper (II) phosphate, what is the student's percent yield?

UNIT 9 TEST REVIEW WORKSHEET

1.) A reaction between methane and sulfur produces carbon disulfide (CS_2), a liquid often used in the production of cellophane.

___ CH_4 + ___ S_8 → ___ CS_2 + ___ H_2S

If 1.50 moles of S_8 are used, (A) how many moles of CS_2 are produced?
(B) How many moles of H_2S are produced?

2.) Lead (II) oxide is obtained by roasting galena, lead (II) sulfide, in air.

___ PbS + ___ O_2 → ___ PbO + ___ SO_2

(A) Determine the theoretical yield (in grams) of PbO if 200.0 grams of PbS are heated.
(B) What is the percent yield if 170.0 grams of PbO are obtained?

3.) Some rockets are fueled by the reaction of hydrazine (N_2H_2) and hydrogen peroxide (H_2O_2). How many moles of nitrogen gas can be produced by reacting 255 grams of hydrazine with excess hydrogen peroxide?

___ N_2H_2 + ___ H_2O_2 → ___ N_2 + ___ H_2O

4.) One in a series of reactions that inflate automobile air bags is the decomposition of sodium azide (NaN_3).

__ NaN_3 → ___ Na + ___ N_2

Determine the mass of N_2 produced if 100.0 grams of NaN_3 are decomposed.

5.) Titanium is a transition metal used in many alloys because it is extremely strong and lightweight. Titanium tetrachloride ($TiCl_4$) is extracted from titanium oxide using chlorine and carbon.

_____ TiO_2 + _____ C + ___ Cl_2 → _____ $TiCl_4$ + _____ CO_2

If you begin with 1.25 moles of TiO_2, what mass of Cl_2 gas is needed?

6.) How many molecules of iodine can be produced by the complete reaction of 43.97 grams of KI?

___ $CuCl_2$ + ___ KI → ___ CuI + ___ KCl + ___ I_2

7.) What mass of ammonia (NH_3) is needed to react completely with oxygen to produce 3.54×10^{24} molecules of water?

___ NH_3 + ___ O_2 → ___ NO + ___ H_2O

Stoichiometry Problems 1 wksht.
1.) 1.34 moles O_2 2.) 8.02 g Al 3.) 0.980 g O_2 4.) 6.0 moles O_2 5.) 22 g 6.) 64 g O_2
7.) 48 g O_2 8.) 0.50 moles Al_2O_3 9.) 1.94 g Na_2O 10.) 5.16 g H_2O 11.) 142.1 g $Al_2(SO_4)_3$
12.) (A) 183 g HCl (B) 238 g $MgCl_2$; 5.00 g H_2 13.) 1.16×10^{27} mcs CO_2

Percent Yield wksht.
1.) (A) 0.147 moles (B) 17.2 g (C) 95.9 % 2.) (A) 146 g (B) 102 % 3.) (A) 7.95 g (B) 84.3 %

Unit 9 Test Review wksht.
1.) (A) 3.00 moles CS_2 (B) 6.00 moles H_2S 2.) (A) 186.6 g PbO (B) 91.10 % 3.) 8.50 moles N_2
4.) 64.60 g N_2 5.) 178 g Cl_2 6.) 3.988×10^{22} mcs I_2 7.) 66.6 g NH_3

MOLE RELATIONSHIP IN A CHEMICAL REACTION LAB

The Law of Conservation of Matter states that "matter is neither created nor destroyed in a chemical reaction." In other words, the total mass of the reactants must equal the total mass of the products in a chemical reaction. Chemical equations are balanced so that they do not contradict the law of conservation of matter. The coefficients used to balance an equation also give the relative number of moles of reactants and products.

In this activity, you will test the Law of Conservation of Matter by causing a chemical reaction to occur with a given amount of reactant. You will then carefully determine the mass of one of the products. With these measurements, you will be able to calculate the moles of one reactant and one product and compare the number of moles. From the balanced equation, you should be able to see the relationship between the number of moles of a reactant and the number of moles of a product.

OBJECTIVES

- predict a balanced equation for the reaction taking place
- react a known mass of Na_2CO_3 with excess HCl
- calculate the mole ratio between Na_2CO_3 and NaCl
- determine whether your results support the Law of Conservation of Matter

EQUIPMENT

- goggles & apron
- evaporating dish
- dropper pipet
- balance
- lab burner/oven/hot plate
- 250 mL beaker
- forceps or tongs
- watch glass

PROCEDURE

* SAFETY GOGGLES AND LAB APRON MUST BE WORN AT ALL TIMES DURING THIS EXPERIMENT! *

1. Clean and dry an evaporating dish. Determine the mass of the empty, dry evaporating dish to the nearest 0.01 g.
2. With a spatula, add about 1.0 grams of sodium carbonate to the evaporating dish, and read the mass to the nearest 0.01 g. (NOTE: You should not attempt to measure exactly 1.0 g since it is only a reference point. For example, mass readings of 0.87 and 1.12 would be equally acceptable.)
3. Cover the evaporating dish with a watch glass. Using the dropper bottle, carefully add hydrochloric acid to the evaporating dish (that already has the Na_2CO_3 in it).

CAUTION: HCl causes burns; avoid skin & eye contact. Rinse spills with plenty of water.

Allow the drops to enter the lip of the evaporating dish so that they gradually flow down the side.

4. Continue adding the acid slowly until the reaction has stopped. Do not add more acid than is needed to complete the reaction. (If you add more than is needed, the rest of the lab will take longer.)
5. Tilt the dish from side to side to make sure the HCl has reacted all of the Na_2CO_3. If any unreacted Na_2CO_3 remains, add a few more drops of HCl to complete the reaction. (The reaction is complete when there is no white powder left in the evaporating dish and HCl can be added without any fizzing occurring.) Remove the watch glass cover. Rinse the underside of the watch glass with a very small amount of water. Be careful to wash all material into the evaporating dish.
6. Heat the liquid in the evaporating dish until it boils **GENTLY**. Take care to avoid loss of liquid from boiling over. Continue to dry the solid slowly until all moisture appears to have evaporated.
7. Remove the dish from the heat and **allow it to cool**. Then measure and record the mass to the nearest 0.01 g.
8. After massing, the contents of the dish may be rinsed down the drain using plenty of water. Clean all lab equipment and return it to the container.

DATA TABLE

Mass of empty evaporating dish	____________________g
Mass of evaporating dish & Na_2CO_3	____________________g
Mass of Na_2CO_3	____________________g
Mass of evaporating dish & NaCl	____________________g
Mass of NaCl	____________________g

QUESTIONS AND CALCULATIONS

1. One of the products in this reaction was NaCl, the other two products were gases. These gases are also produced in a combustion reaction. Write the balanced equation for the reaction in this experiment.

    ________________ + ________________ → NaCl + ________________ + ________________

2. From your balanced equation, what is the mole ratio between Na_2CO_3 and NaCl? ______ : ______

3. Suppose you had started with 3.25 moles of sodium carbonate. (A) How many moles of sodium chloride would you expect to be formed? (B) Explain.

    (A) ________________

    (B) ____

4. Calculate the number of moles of Na_2CO_3 used in this reaction. answer = ______________________
    Show your work here:

5. Calculate the number of moles of NaCl produced in this reaction. answer = ____________________
    Show your work here:

6. From the data you collected in the lab, what is the mole ratio between Na_2CO_3 and NaCl?
    Show your work here:
    answer = __1__ : ______

7. Starting with the mass of Na_2CO_3 that you actually used in the experiment, determine the theoretical yield (in grams) of NaCl in this experiment. (Stoichiometry problem!)
    Show your work here:

8. Compare the theoretical yield with your actual yield. What is your percent yield?

$$\% \text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100 \qquad \text{answer} = \underline{\hspace{3cm}} \times 100 =$$

(Note: Theoretical yield is answer from #7. Actual yield is the last line of your data table.)

9. Was your percent yield more or less than 100 %? Explain what your percent yield means. (Explain why – in terms of the lab procedure - your percent yield was less than or more than 100 %.) Please answer this question below #10. Do not try to squeeze your answer in this little amount of space.

10. Write a paragraph describing the observations of this chemical reaction. Also include in this paragraph:
    - How did you know that a chemical reaction occurred?
    - What were two (2) sources of error in this experiment (in terms of procedure - not faulty equipment or miscalculations)?
    - What could be done to prevent these errors if you did the experiment again?

Stoichiometry Assignment

1.) Given the equation: __ H_3PO_4 + __ $Ca(OH)_2$ → __ H_2O + __ $Ca_3(PO_4)_2$

(A) What is the mole ratio between $Ca(OH)_2$ and H_2O?

(Write answer as __ moles $Ca(OH)_2$: __ moles H_2O)

If 1.67 moles of $Ca(OH)_2$ completely react with excess H_3PO_4

(B) How many moles of H_2O can be produced?

(C) How many moles of $Ca_3(PO_4)_2$ can be produced?

2.) How many moles of chlorine are needed to produce 35.2 grams of $FeCl_3$ according to this equation? __ Cl_2 + __ FeI_2 → __ $FeCl_3$ + __ I_2

3.) How many grams of calcium carbide are needed to completely react with 2.942 moles of water?

__ CaC_2 + __ H_2O → __ $Ca(OH)_2$ + __ C_2H_2

4.) How many grams of CuI can be produced from the complete reaction of 4.397 moles of KI?

__ $CuCl_2$ + __ KI → __ CuI + __ KCl + __ I_2

(Balancing hint: get an even number of Is on the product side first)

5.) Given the equation: __ $(NH_4)_2Cr_2O_7$ → __ Cr_2O_3 + __ H_2O + __ N_2

Answer these questions using the equation above:

(A) What type of reaction is represented?

(B) How many moles of water are produced by the complete decomposition of 28 grams of $(NH_4)_2Cr_2O_7$?

(C) What is the name of the reactant compound?

6.) How many grams of ammonia (NH_3) are needed to react completely with oxygen to produce 35.4 grams of water?

__ NH_3 + __ O_2 → __ NO + __ H_2O