

Chem. I Notes – Ch. 11 – STOICHIOMETRY

NOTE: Vocabulary terms are in **boldface and underlined**. Supporting details are in *italics*.

11.1 notes

1 MOLE = 6.02×10^{23} representative particles representative particles = ATOMS, IONS, MOLECULES, & FORMULA UNITS (“funs”)	
CONVERSION FACTOR SUMMARY:	
$\frac{6.02 \times 10^{23} \text{ representative particles}}{1 \text{ MOLE}}$	$\frac{1 \text{ MOLE}}{6.02 \times 10^{23} \text{ representative particles}}$
$\frac{\text{MOLAR MASS (g)}}{1 \text{ MOLE}}$	$\frac{1 \text{ MOLE}}{\text{MOLAR MASS (g)}}$
$\frac{22.4 \text{ L (for a gas at STP)}}{1 \text{ MOLE}}$	$\frac{1 \text{ MOLE}}{22.4 \text{ L (for a gas at STP)}}$

I. Stoichiometry

A. **stoichiometry**—using balanced chemical equations to obtain info.

B. information from a balanced equation

- 1) *numbers of particles*: atoms, ions, molecules, formula units
- 2) *numbers of moles = mole ratios = coefficient ratios*
- 3) *mass* = molecular masses from the periodic table
- 4) *volume*, if at STP, 22.4 L = 1 mol of gas

Only mass and atoms are conserved (reactant numbers = product numbers).

	<u>2</u> H ₂ (g)	+	<u>1</u> O ₂ (g)	→	<u>2</u> H ₂ O(g)
# atoms in balancing	4 H		2 O	=	4 H, 2 O
r.p.	2 molecules		1 molecule		2 molecules
mol	2 mol		1 mol		2 mol
g	4(1.0) = 4.0 g		2(16.0) = 32.0 g	=	2(18.0) = 36.0 g
L (STP)	2(22.4) = 44.8 L		22.4 L		2(22.4) = 44.8 L

11.2 notes – stoich calculations

II. **Mole - Mole (MOL – MOL) Conversions**

- A. the most important, most basic stoich calculation
- B. *uses the coefficients of a balanced equation* to compare the amounts of reactants and products
- C. *coefficients are mole ratios*
- D. *the way to go from substance A to substance B*
- E. **mol – mol is the only time the mole number in the conversion is not automatically 1.** (Avogadro’s #, molar mass, and 22.4 L (STP) are all equal to 1 mole.)

MOL – MOL :	$\frac{\text{\# mol B (new, ending substance – what is being asked for)}}{\text{\# mol A (old, starting substance – what is given originally)}}$
$\text{\#} = \text{coefficients}$	

F. examples

- E1) How many moles of carbon monoxide are produced when carbon reacts with 0.750 mol of oxygen?



$$0.750 \text{ mol } O_2 \cdot x \frac{2 \text{ mol } CO}{1 \text{ mol } O_2} = \boxed{1.50 \text{ mol } CO}$$

- E2) Aluminum reacts with oxygen gas to form aluminum oxide. Find the number of moles of both reactants, if 0.661 mol of product is formed.



$$0.661 \text{ mol } Al_2O_3 \cdot x \frac{4 \text{ mol } Al}{2 \text{ mol } Al_2O_3} = \boxed{1.32 \text{ mol } Al} \quad 0.661 \text{ mol } Al_2O_3 \cdot x \frac{3 \text{ mol } O_2}{2 \text{ mol } Al_2O_3} = \boxed{0.992 \text{ mol } O_2}$$

III. **MASS – MASS Conversions – Using molar mass in stoich problems to predict masses of reactants and/or products**

- A. a balanced chemical equation can be used to compare masses of reactants and products
 B. *mass – mass* cannot change which substance you are dealing with; only *mol – mol* can do that

“MASS – MASS”: $\text{GIVEN g A} \cdot x \frac{1 \text{ mol A}}{PT \text{ g A}} \cdot x \frac{CE \text{ mol B}}{CE \text{ mol A}} \cdot x \frac{PT \text{ g B}}{1 \text{ mol B}}$
PT = periodic table, molar mass *CE = coefficients*

C. examples

- E3) How many grams of hydrochloric acid are made from the reaction of 0.500 g of hydrogen gas with excess chlorine gas?



GAME PLAN: *KNOWN, PER.TABLE, COEFF., PER.TABLE*

$$0.500 \text{ g } H_2 \cdot x \frac{1 \text{ mol } H_2}{2.0 \text{ g } H_2} \cdot x \frac{2 \text{ mol } HCl}{1 \text{ mol } H_2} \cdot x \frac{36.5 \text{ g } HCl}{1 \text{ mol } HCl} = \boxed{18 \text{ g } HCl}$$

- E4) Calculate the numbers of grams of products formed when 25.0 g of sodium nitrate decomposes into sodium nitrite and oxygen.



$$25.0 \text{ g } NaNO_3 \cdot x \frac{1 \text{ mol } NaNO_3}{85.0 \text{ g } NaNO_3} \cdot x \frac{2 \text{ mol } NaNO_2}{2 \text{ mol } NaNO_3} \cdot x \frac{69.0 \text{ g } NaNO_2}{1 \text{ mol } NaNO_2} = \boxed{20.3 \text{ g } NaNO_2}$$

$$25.0 \text{ g } NaNO_3 \cdot x \frac{1 \text{ mol } NaNO_3}{85.0 \text{ g } NaNO_3} \cdot x \frac{1 \text{ mol } O_2}{2 \text{ mol } NaNO_3} \cdot x \frac{32.0 \text{ g } O_2}{1 \text{ mol } O_2} = \boxed{4.71 \text{ g } O_2}$$

IV. MOLE-MASS (or MASS- MOLE) Conversions

“MASS – MOLE”:

$$\frac{\text{GIVEN g A}}{PT \text{ g A}} \times \frac{1 \text{ mol A}}{PT \text{ g A}} \times \frac{CE \text{ mol B}}{CE \text{ mol A}}$$

“MOLE – MASS”:

$$\frac{\text{GIVEN mol A}}{PT \text{ g A}} \times \frac{CE \text{ mol B}}{CE \text{ mol A}} \times \frac{PT \text{ g B}}{1 \text{ mol B}}$$

PT = periodic table, molar mass CE = coefficients

E5) How many g of water are produced from the complete combustion of 0.6829 mol of C₂H₂?



$$0.6829 \text{ mol C}_2\text{H}_2 \times \frac{2 \text{ mol H}_2\text{O}}{2 \text{ mol C}_2\text{H}_2} \times \frac{18.0 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = \boxed{12.3 \text{ g H}_2\text{O}}$$

E6) Using the equation 2C₂H₂ + 5O₂ → 4CO₂ + 2H₂O how many moles of O₂ would be needed to produce 56.09 g of CO₂?

$$56.09 \text{ g CO}_2 \times \frac{1 \text{ mol CO}_2}{44.0 \text{ g CO}_2} \times \frac{5 \text{ mol O}_2}{4 \text{ mol CO}_2} = \boxed{1.59 \text{ mol O}_2}$$

V. MASS-VOLUME (or VOLUME – MASS) Conversions -
Using molar volume in stoich problems

“MASS – VOLUME”: (gases @ STP)

$$\frac{\text{GIVEN g A}}{PT \text{ g A}} \times \frac{1 \text{ mol A}}{PT \text{ g A}} \times \frac{CE \text{ mol B}}{CE \text{ mol A}} \times \frac{22.4 \text{ L B}}{1 \text{ mol B}}$$

“VOLUME – MASS”: (gases @ STP)

$$\frac{\text{GIVEN L A}}{22.4 \text{ L A}} \times \frac{1 \text{ mol A}}{22.4 \text{ L A}} \times \frac{CE \text{ mol B}}{CE \text{ mol A}} \times \frac{PT \text{ g B}}{1 \text{ mol B}}$$

PT = periodic table, molar mass CE = coefficients

E7) How many L of hydrogen are produced from the decomposition of 3.50 g of water at STP?



$$3.50 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.0 \text{ g H}_2\text{O}} \times \frac{2 \text{ mol H}_2}{2 \text{ mol H}_2\text{O}} \times \frac{22.4 \text{ L H}_2}{1 \text{ mol H}_2} = \boxed{4.36 \text{ L H}_2}$$

E8) Using the equation 2C₂H₂ + 5O₂ → 4CO₂ + 2H₂O how many liters of oxygen gas are needed when 5.02 g of C₂H₂ undergoes complete combustion under STP conditions?

$$5.02 \text{ g C}_2\text{H}_2 \times \frac{1 \text{ mol C}_2\text{H}_2}{26.0 \text{ g C}_2\text{H}_2} \times \frac{5 \text{ mol O}_2}{2 \text{ mol C}_2\text{H}_2} \times \frac{22.4 \text{ L O}_2}{1 \text{ mol O}_2} = \boxed{10.8 \text{ L O}_2}$$

VI. VOLUME-VOLUME Conversions

“VOLUME – VOLUME”: (gases @ STP)

$$\frac{\text{GIVEN L A}}{22.4 \text{ L A}} \times \frac{1 \text{ mol A}}{\text{CE mol A}} \times \frac{\text{CE mol B}}{\text{CE mol A}} \times \frac{22.4 \text{ L B}}{1 \text{ mol B}}$$

CE = coefficients (SHORT CUT: compare coefficients!)

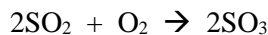
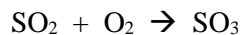
- E9) How many liters of carbon dioxide are produced from 0.252 L of hydrochloric acid reacting with excess sodium bicarbonate?



$$0.252 \text{ L HCl} \times \frac{1 \text{ mol HCl}}{22.4 \text{ L HCl}} \times \frac{1 \text{ mol CO}_2}{1 \text{ mol HCl}} \times \frac{22.4 \text{ L CO}_2}{1 \text{ mol CO}_2} = \boxed{0.252 \text{ L CO}_2}$$

SHORTCUT: coefficients = 1 mol HCl to 1 mol CO₂, so 0.252 L HCl = $\boxed{0.252 \text{ L CO}_2}$

- E10) How many L of sulfur trioxide are produced from the reaction of 36.1 L of oxygen with sulfur dioxide at STP?



$$36.1 \text{ L O}_2 \times \frac{1 \text{ mol O}_2}{22.4 \text{ L O}_2} \times \frac{2 \text{ mol SO}_3}{1 \text{ mol O}_2} \times \frac{22.4 \text{ L SO}_3}{1 \text{ mol SO}_3} = \boxed{72.2 \text{ L SO}_3}$$

SHORTCUT: coefficient of O₂ = 1; coefficient of SO₃ = 2 36.1 L x 2 = $\boxed{72.2 \text{ L SO}_3}$

VII. MASS – PARTICLE (or PARTICLE-MASS) Conversions

“MASS – PARTICLE”: (specify the type of r.p.)

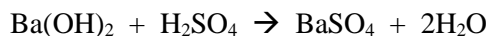
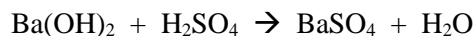
$$\frac{\text{GIVEN g A}}{\text{PT g A}} \times \frac{1 \text{ mol A}}{\text{CE mol A}} \times \frac{\text{CE mol B}}{\text{CE mol A}} \times \frac{(6.02 \times 10^{23}) \text{ r.p. B}}{1 \text{ mol B}}$$

“PARTICLE – MASS”: (specify the type of r.p.)

$$\frac{\text{GIVEN r.p. A}}{(6.02 \times 10^{23}) \text{ r.p. A}} \times \frac{1 \text{ mol A}}{\text{CE mol A}} \times \frac{\text{CE mol B}}{\text{CE mol A}} \times \frac{\text{PT g B}}{1 \text{ mol B}}$$

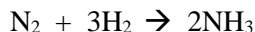
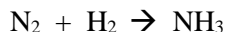
PT = periodic table, molar mass CE = coefficients

- E11) How many r.p. of barium sulfate are made from reacting 5.33 g of barium hydroxide with sulfuric acid?



$$5.33 \text{ g Ba(OH)}_2 \times \frac{1 \text{ mol Ba(OH)}_2}{171.3 \text{ g Ba(OH)}_2} \times \frac{1 \text{ mol BaSO}_4}{1 \text{ mol Ba(OH)}_2} \times \frac{6.02 \times 10^{23} \text{ fun. BaSO}_4}{1 \text{ mol BaSO}_4} = \boxed{1.87 \times 10^{22} \text{ fun. BaSO}_4}$$

- E12) How many r.p. of NH₃ are produced from reacting 2.07 g of hydrogen with nitrogen?



$$2.07 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.0 \text{ g H}_2} \times \frac{2 \text{ mol NH}_3}{3 \text{ mol H}_2} \times \frac{6.02 \times 10^{23} \text{ molecules NH}_3}{1 \text{ mol NH}_3} = \boxed{4.2 \times 10^{23} \text{ molecules NH}_3}$$

11.3 notes

VIII. Limiting Reactant (Limiting Reagent)

- A. **limiting reactant**—the reactant present in the smallest quantity, limiting the amount of product being made
B. **excess reactant**—the reactant present in a greater quantity than the limiting reactant; does not limit formation of product

C. example

E13) Aluminum metal reacts with chlorine gas to form aluminum chloride.

If 5.40 mol of aluminum and 8.00 mol of chlorine are available...

- A) Which is the limiting reactant? C) How many moles of product form?
B) Which is the excess reactant? D) How many moles of excess reactant are left over?



$$5.40 \text{ mol Al} \times \frac{3 \text{ mol Cl}_2}{2 \text{ mol Al}} = 8.10 \text{ mol Cl}_2 \text{ needed ...}$$

This is the amount of Cl₂ needed to react with 5.40 mol Al. There are only 8.00 mol available.

- A) Cl₂ is the limiting reagent. If Cl₂ is limiting, Al must be in excess. Check it anyway.

$$8.00 \text{ mol Cl}_2 \times \frac{2 \text{ mol Al}}{3 \text{ mol Cl}_2} = 5.33 \text{ mol Al needed}$$

- B) Al is the excess reagent.
C) Use the limiting reagent to find the product, since that is the chemical limiting the yield.

$$8.00 \text{ mol Cl}_2 \times \frac{2 \text{ mol AlCl}_3}{3 \text{ mol Cl}_2} = \text{5.33 mol AlCl}_3$$

- D) Remaining excess reagent = (given – used) 5.40 – 5.33 mol Al = 0.07 mol Al

11.4 notes

IX. Percent Yield

- A. **percent yield**—percentage of product recovered; comparison of actual and theoretical yields
B. **actual yield**—amount of product obtained in lab
C. **theoretical yield**—amount of product predicted by the math (theory)

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

D. examples

E14) 35.0 g of product should be recovered from an experiment. A student collects 22.9 g at the end of the lab. What is the percent yield?

$$\frac{22.9 \text{ g}}{35.0 \text{ g}} \times 100 = \text{65.4\%}$$

E15) What is the percent yield if 2.89 g of sodium chloride is produced when 1.99 g of hydrochloric acid reacts with excess sodium hydroxide?



Actual yield = 2.89 g NaCl

Theoretical yield = ?

$$1.99 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.5 \text{ g HCl}} \times \frac{1 \text{ mol NaCl}}{1 \text{ mol HCl}} \times \frac{58.5 \text{ g NaCl}}{1 \text{ mol NaCl}} = 3.19 \text{ g NaCl} \text{ theoretical yield}$$

$$\% \text{ YIELD} = \frac{\text{ACTUAL YIELD}}{\text{THEORETICAL YIELD}} \times 100 = \frac{2.89 \text{ g NaCl}}{3.19 \text{ g NaCl}} = \boxed{90.6\%}$$

