Name: SOLUTIONS
Hour: ________ Date: ________

Chem B Unit 7, Day 4: Gas stoichiometry and Limiting Reagents

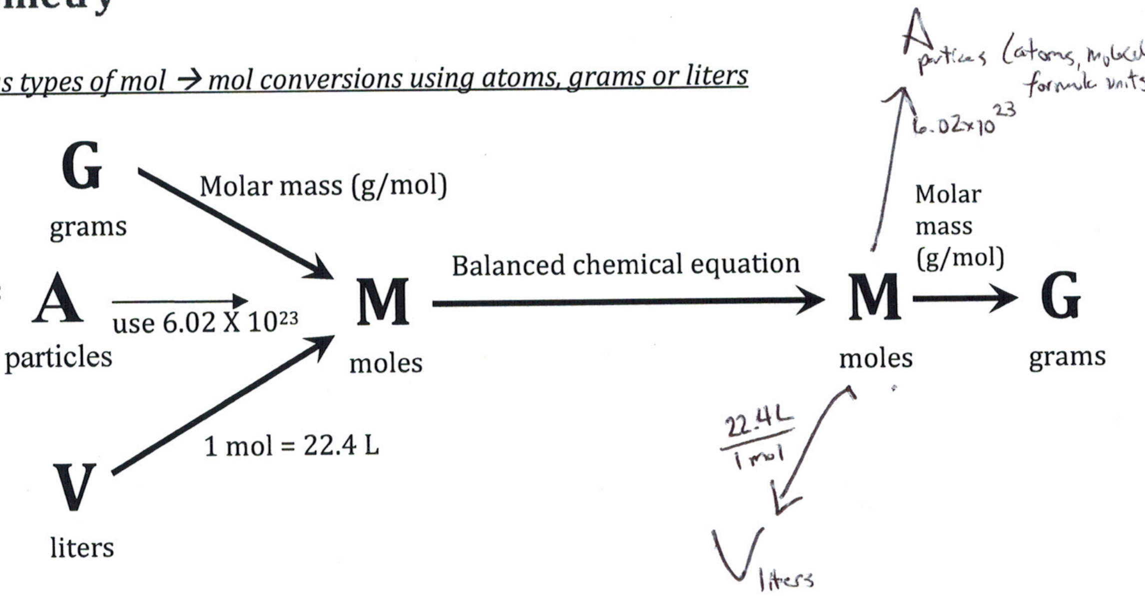
Part I: Gas stoichiometry

Various types of mol → mol conversions using atoms, grams or liters

Option 1: *Given mass:*

Option 2: Given # particles:

Option 3: *Given volume:*



Determining the volume of a gas

*The **temperature** and **pressure** conditions of a gas are important for determining just how much room a gas will occupy.*

At STP: Standard pressure + temperature (1 atm and 0°c) **the volume of 1 mole of gas:** 22.4 L

1.) How many moles of $CO_{2\,(g)}$ are present in 26.1 L at STP?

$$\frac{26.1\ L \mid 1\ mol\ CO_2}{\mid 22.4\ L\ CO_2} = \boxed{1.17\ mol\ CO_2}$$

2.) How many moles of Cl_2 gas are present in 4.45 L at STP?

$$\frac{4.45\ L\ Cl_2 \mid 1\ mol\ Cl_2}{\mid 22.4\ L\ Cl_2} = \boxed{0.199\ L\ Cl_2}$$

3.) How many molecules of ammonia, NH_3, are present in 34.5 L of NH_3 gas at STP? roadmap: $V_{NH_3} \rightarrow mol_{NH_3} \rightarrow A_{NH_3}$

$$\frac{34.5\ L\ NH_3 \mid 1\ mol\ NH_3 \mid 6.02\times10^{23}\ molecules\ NH_3}{\mid 22.4\ L\ NH_3 \mid 1\ mol\ NH_3} = \boxed{9.27\times10^{23}\ molecules\ NH_3}$$

4.) How much space would 1.35 moles of O_2 take up (i.e. what is the volume in liters of this gas) at STP?

roadmap: $mol_{O_2} \rightarrow V_{O_2}$

$$\frac{1.35\ mol\ O_2 \mid 22.4\ L}{\mid 1\ mol\ O_2} = \boxed{30.2\ L\ O_2}$$

Using Volume of a Gas in Stoichiometry

5.) How many liters of ammonia could form if 13.6 moles nitrogen gas were reacted with excess hydrogen gas?

a. Write the balanced chemical equation: $N_2 + 3H_2 \rightarrow 2NH_3$

b. Use the road map to go from moles of one substance to volume of another:

$\text{mol}_{N_2} \rightarrow \text{mol}_{NH_3} \rightarrow V_{NH_3}$ (2 calculations)

$$\frac{13.6 \text{ mol } N_2 \,|\, 2 \text{ mol } NH_3 \,|\, 22.4 \text{ L } NH_3}{\,|\, 1 \text{ mol } N_2 \,|\, 1 \text{ mol } NH_3} = \boxed{609 \text{ L } NH_3}$$

6.) In a combustion reaction, what volume of oxygen gas (end pt.) is needed to react with 15.4 liters of propane, C_3H_8 (start pt)?

forms $CO_2 + H_2O$

$\underline{1}\ C_3H_8 + \underline{5}\ O_2 \rightarrow \underline{3}\ CO_2 + \underline{4}\ H_2O$

roadmap: $V_{C_3H_8} \rightarrow \text{mol}_{C_3H_8} \rightarrow \text{mol}_{O_2} \rightarrow V_{O_2}$

math: $$\frac{15.4 \text{ L } C_3H_8 \,|\, 1 \text{ mol } C_3H_8 \,|\, 5 \text{ mol } O_2 \,|\, 22.4 \text{ L } O_2}{\,|\, 22.4 \text{ L } C_3H_8 \,|\, 1 \text{ mol } C_3H_8 \,|\, 1 \text{ mol } O_2} = \boxed{77.0 \text{ L } O_2 \text{ needed for this reaction}}$$

7.) If 0.10 mol of hydrochloric acid, HCl, is reacted with excess magnesium, Mg, what volume of hydrogen gas would evolve? (start) (end)

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2\,(g)} + MgCl_{2\,(aq)}$$

roadmap: $\text{mol}_{HCl} \rightarrow \text{mol}_{H_2} \rightarrow V_{H_2}$

math: $$\frac{0.10 \text{ mol } HCl \,|\, 1 \text{ mol } H_2 \,|\, 22.4 \text{ L } H_2}{\,|\, 2 \text{ mol } HCl \,|\, 1 \text{ mol } H_2} = \boxed{1.12 \text{ L } H_2}$$

8.) If 0.6 grams of magnesium, Mg, reacts with excess hydrochloric acid, HCl, what volume of hydrogen gas would evolve? (start pt) (end pt)

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2\,(g)} + MgCl_{2\,(aq)}$$

roadmap: $G_{Mg} \rightarrow \text{mol}_{Mg} \rightarrow \text{mol}_{H_2} \rightarrow V_{H_2}$

math: $$\frac{0.6 \text{ g } Mg \,|\, 1 \text{ mol } Mg \,|\, 1 \text{ mol } H_2 \,|\, 22.4 \text{ L } H_2}{\,|\, 24.3 \text{ g } Mg \,|\, 1 \text{ mol } Mg \,|\, 1 \text{ mol } H_2} = 0.55 \text{ L } H_2 = \boxed{0.6 \text{ L } H_2}$$

(1 sig fig) →

Part II: Limiting Reactants

Key tip! If 2 amounts of reactants given then it's a LR problem! Plan to do 2 sets of calculations!

If 0.6 grams of magnesium, Mg, reacts with 0.10 mol hydrochloric acid, HCl, what volume of hydrogen gas would evolve?

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow H_{2\,(g)} + MgCl_{2\,(aq)}$$

From previous 2 problems, we know
0.6 g Mg will produce **0.6 L H_2** — we can only produce this much H_2 because all of the Mg will be gone!
while 0.1 mol HCl will produce 1.12 L H_2

What is the limiting reagent in this reaction? Mg (because it will run out 1st)

What is the excess reagent? HCl (because we have plenty of it – some will be left over once Mg has run out ∴ "excess")

We tend to use the cheap and abundant chemical as our excess reagent and the hard to find or expensive chemical as our limiting reagent.

9.) When 0.500 mol aqueous $Ag(NO_3)_3$ [2] is mixed with 0.500 mol aqueous $BaCl_2$, how many moles of precipitate will be formed? ← worksheet error alert!

a. **Predict the precipitate:** $Ag(NO_3)_{3\,(aq)}$ [2] $+ BaCl_{2\,(aq)} \rightarrow AgCl_{2\,(s)} + Ba(NO_3)_{2\,(aq)}$

b. **Make sure the equation is balanced.** ✓

c. **Two calculations**! Determine the amount of precipitate that will be formed given each of the amounts of reactants.

$$\frac{0.500 \text{ mol } Ag(NO_3)_2}{} \cdot \frac{1 \text{ mol } AgCl_2}{1 \text{ mol } Ag(NO_3)_2} = 0.500 \text{ mol } AgCl_2$$

$$\frac{0.500 \text{ mol } BaCl_2}{} \cdot \frac{1 \text{ mol } AgCl_2}{1 \text{ mol } BaCl_2} = 0.500 \text{ mol } AgCl_2$$

Both will be completely used up in their reaction.

0.500 mol $AgCl_2$ can be formed

LR problem!

10.) If 5.0 grams of lead (II) nitrate are allowed to react with 5.0 grams of sodium chromate, how many moles of lead (II) chromate will be produced?

a. **Balanced chemical equation:** $Pb(NO_3)_2 + Na_2CrO_4 \rightarrow PbCrO_4 + 2\,NaNO$

b. **Calculations:** (1) $G_{Pb(NO_3)_2} \rightarrow mol_{Pb(NO_3)_2} \rightarrow mol_{PbCrO_4}$

(2) $G_{Na_2CrO_4} \rightarrow mol_{Na_2CrO_4} \rightarrow mol_{PbCrO_4}$

(1) 5.0g $Pb(NO_3)_2$ | 1 mol $Pb(NO_3)_2$ / 345.2 g $Pb(NO_3)_2$ | 1 mol $PbCrO_4$ / 1 mol $Pb(NO_3)_2$ = 0.014 g $PbCrO_4$

(2) 5.0g Na_2CrO_4 | 1 mol Na_2CrO_4 / 161.97 g Na_2CrO_4 | 1 mol $PbCrO_4$ / 1 mol Na_2CrO_4 = 0.031 g $PbCrO_4$

∴ $Pb(NO_3)_2$ is the limiting reagent

11.) If 5.00 L of propane reactions with 10.0 L of oxygen gas how many liters of water will be produced?

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

(1) $V_{C_3H_8} \rightarrow mol_{C_3H_8} \rightarrow mol_{H_2O} \rightarrow V_{H_2O}$

5.00 L C_3H_8 | 1 mol C_3H_8 / 22.4 L C_3H_8 | 4 mol H_2O / 1 mol C_3H_8 | 22.4 L H_2O / 1 mol H_2O = 20.0 L H_2O

(2) $V_{O_2} \rightarrow mol_{O_2} \rightarrow mol_{H_2O} \rightarrow V_{H_2O}$

10.0 L O_2 | 1 mol O_2 / 22.4 L O_2 | 4 mol H_2O / 5 mol O_2 | 22.4 L / 1 mol H_2O = 8.00 L H_2O → O_2 is the limiting reagent

12.) If a hydrogen fuel cell reacts 10.0 grams of hydrogen gas with 10.0 grams of oxygen gas, how many grams of water will *theoretically* be released? 2 $H_2 + O_2 \rightarrow 2H_2O$

(1) $G_{H_2} \rightarrow mol_{H_2} \rightarrow mol_{H_2O} \rightarrow G_{H_2O}$

10.0 g H_2 | 1 mol H_2 / 2.016 g H_2 | 2 mol H_2O / 2 mol H_2 | 18.0152 g H_2O / 1 mol H_2O = 89.4 g H_2O

(2) $G_{O_2} \rightarrow mol_{O_2} \rightarrow mol_{H_2O} \rightarrow G_{H_2O}$

10.0g O_2 | 1 mol O_2 / 31.999 g O_2 | 2 mol H_2O / 1 mol O_2 | 18.052 g H_2O / 1 mol H_2O = 11.3 g H_2O → O_2 is the limiting reagent

13.) CHALLENGE PROBLEM: Alka-Seltzer tablet dissolves in water releasing citric acid and sodium hydrogen carbonate. In a certain experiment 1.00g of $NaHCO_3$ and 1.00g of citric acid, $H_3C_6H_5O_7$, react. How many grams of carbon dioxide are formed? How much excess reactant is left over?

$$3\,NaHCO_3 + H_3C_6H_5O_7 \rightarrow 3H_2O + CO_2 + Na_3C_6H_5O_7$$

Name: SOLUTIONS
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Chem B Unit 7, Day 4 Homework: Gases and LR

Stoichiometry with gases

1.) How many liters of ammonia could form if 24.2 liters of hydrogen gas were reacted with excess nitrogen gas?

a. Write the balanced chemical equation: $N_2 + 3H_2 \rightarrow 2NH_3$

b. Use the road map to go from volume of one substance to volume of another:

(1) $V_{H_2} \rightarrow mol_{H_2} \rightarrow mol_{NH_3} \rightarrow V_{NH_3}$

$$\frac{24.2 \text{ L } H_2}{} \left| \frac{1 \text{ mol } H_2}{22.4 \text{ L } H_2} \right| \frac{2 \text{ mol } NH_3}{3 \text{ mol } H_2} \left| \frac{22.4 \text{ L } NH_3}{1 \text{ mol } NH_3} \right. = 16.1 \text{ L } NH_3$$

2.) How many molecules of carbon dioxide are formed when 6.35 liters of propane, C_3H_8, burn in the presence of excess oxygen?

a. Write the balanced chemical equation: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

b. Use the road map to go from volume of one substance to volume of another:

$V_{C_3H_8} \rightarrow mol_{C_3H_8} \rightarrow mol_{CO_2} \rightarrow A_{CO_2}$

$$\frac{6.35 \text{ L } C_3H_8}{} \left| \frac{1 \text{ mol } C_3H_8}{22.4 \text{ L } C_3H_8} \right| \frac{3 \text{ mol } CO_2}{1 \text{ mol } C_3H_8} \left| \frac{6.02\times10^{23} \text{ molecules } CO_2}{1 \text{ mol } CO_2} \right. = 5.11\times10^{23} \text{ molecules } CO_2$$

3.) How many molecules of oxygen are produced by the decomposition of 6.54 g of potassium chlorate ($KClO_3$)?

$$2KClO_{3(s)} \rightarrow 2KCl_{(s)} + 3O_{2(g)}$$

$G_{KClO_3} \rightarrow mol_{KClO_3} \rightarrow mol_{O_2} \rightarrow A_{O_2}$

$$\frac{6.54 \text{ g } KClO_3}{} \left| \frac{1 \text{ mol } KClO_3}{122.55 \text{ g } KClO_3} \right| \frac{3 \text{ mol } O_2}{2 \text{ mol } KClO_3} \left| \frac{6.02\times10^{23} \text{ molecules } O_2}{1 \text{ mol } O_2} \right. = 1.93\times10^{22} \text{ molecules } O_2 \text{ gas will be formed}$$

4.) Calculate the volume of sulfur dioxide, in milliliters, produced when 27.9 mL O_2 reacts with carbon disulfide. (Recall that 1000 mL = 1 L).

$$CS_{2(l)} + 3O_{2(g)} \rightarrow CO_{2(g)} + 2SO_{2(g)}$$

$mL_{O_2} \rightarrow V_{O_2} \rightarrow mol_{O_2} \rightarrow mol_{SO_2} \rightarrow V_{SO_2} \rightarrow mL_{SO_2}$

$$\frac{27.9 \text{ mL } O_2}{} \left| \frac{1 \text{ L } O_2}{1000 \text{ mL } O_2} \right| \frac{1 \text{ mol } O_2}{22.4 \text{ L } O_2} \left| \frac{2 \text{ mol } SO_2}{3 \text{ mol } O_2} \right| \frac{22.4 \text{ L } SO_2}{1 \text{ mol } SO_2} \left| \frac{1000 \text{ mL } SO_2}{1 \text{ L } SO_2} \right. = 18.6 \text{ mL } SO_2$$