CH301 Unit 1

FUNDAMENTALS REVIEW: MOLECULES TO MOLES & STOICHIOMETRY

MATERIAL COVERED: LE01, HW01

Goals for Our First Review

- Get acquainted
- Talk about what you're expected to know **going into the first day of chemistry content**
- Discuss the fundamentals of chemistry:
  - Molecules to Moles
  - Stoichiometry Terminology
  - Reaction Stoichiometry
- Discuss the "secret" to doing well in this course

- Where to find me on Social Media:

Jimmy Wadman on Spotify, @jhwadman on IG

Jimmy Wadman on Youtube!!!!

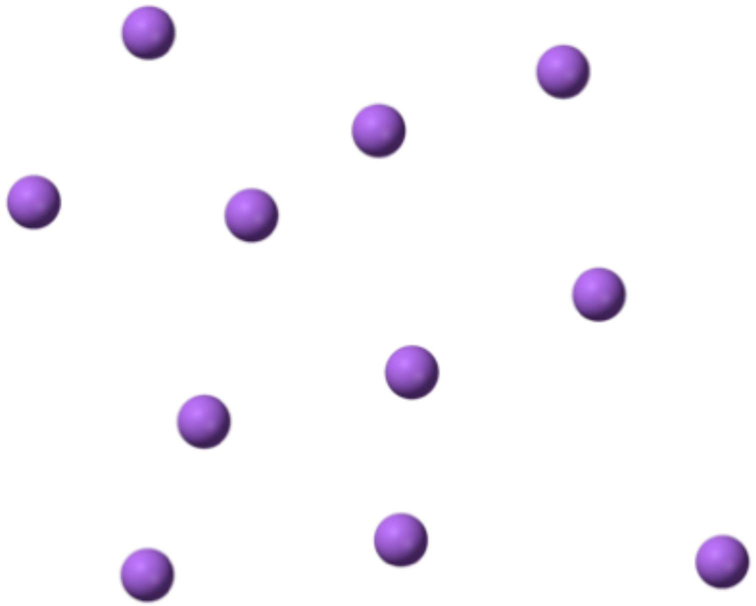
When the ~~professor~~ TA is passionate about teaching and you genuinely understand and enjoy the class

How to Succeed in CH301

- The main secret to doing well in CH301 is no secret at all; rather, it is one very obvious technique that too few people actually follow:
  - Thoroughly working through Learning Exercises and reviewing the gchem chapters BEFORE going to class increases retention of the material
  - This makes you absorb material better during lecture, makes homework easier, and relieves stress when it is time to study
- Take advantage of extra help
  - Get help right away ; don't wait until the week of the exam to get clarification
  - Listening to other students' questions can help. When studying in a group, be the teacher **not the student copying your friends' homework answers**.
- However, most of the learning must be done on your own
  - By exam time, you should be able to knock out practice problems and redo homework questions **on your own without the help of your peers**.
  - Be honest with yourself and **work hard** to understand the material. CH301 is challenging but getting a good grade is very rewarding.
- Take some time to explore Canvas, gchem, and the class website (McCord only)

Pre-CH301 Knowledge

- You are expected to come into CH301 with a little bit of prior chemistry knowledge:
  - You will not be provided with prefixes (milli, kilo, micro, nano, etc.)
  - You should understand the relationship between molar mass and atomic mass units; moles and atoms
    - 1 gram = 6.022×10^{23} amu
    - 1 mole = 6.022×10^{23} atoms/molecules
  - Be able to read the periodic table: the masses of elements are given in amu (the weight of one atom), but can also be read as molar mass(grams per mole of the element).
  - **You should be able to do stoichiometry as second nature by the first exam (or be okay with getting 8-20 points off to start)**
  - Apply dimensional analysis to convert units
  - Understand the relationship between Celsius and Kelvin. **Kelvin = Celsius + 273.15**
    - Also recognize that we use Kelvin for MOST calculations in chemistry



25°C + 273.15 = 298.15 K

→ Composition Stoich.

Molecules, Moles, and Mass

You are expected to know how to convert between molecules, moles, and molar mass.

Here's how you do it:

→ $6.022 \times 10^{23}\ mol^{-1}$

1. From Molecules to Moles

   # molecules ÷ N_A = # of moles

   $$\frac{\#\ \text{molecules}}{N_A} = \#\ \text{moles}$$

2. From Moles to Molecules

   # mol × N_A = # molecules

   $$\#\ \text{moles} \cdot N_A = \#\ \text{molecules}$$

3. From Moles to Mass

   # mol × g/mol = g →

   $$\#\ \text{moles} \cdot MW = \text{mass}$$

4. From Mass to Moles

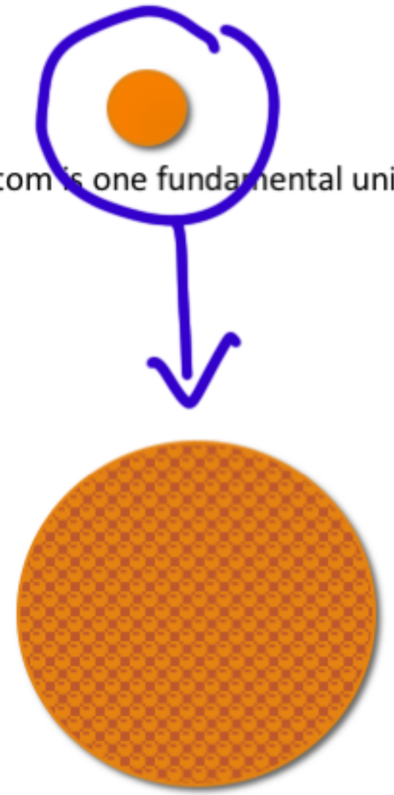
   g × mol/g = mol →

   $$\frac{\text{mass}}{MW} = \#\ \text{moles}$$

5. Molecular Weight

   g / # mol = molar mass

   $$\frac{\text{mass}}{\#\ \text{moles}} = MW$$



1 mole is 6.022×10^{23} fundamental units

Molecules, Moles, and Mass

You are expected to know how to convert between molecules, moles, and molar mass.

Here's how you do it:

1. From Molecules to Moles
   - Remember: Avogadro's number ($N_A = 6.022 \times 10^{23}\ mol^{-1}$) represents the number of molecules in a mole.
2. From Moles to Molecules
   - On the exam, what if you forget if you multiply or divide by Avogadro's number? Remember, a mole is a "packet" of molecules. Converting from moles to molecules should always give you a **bigger number**
3. From Moles to Mass
4. From Mass to Moles
5. Molecular Weight

$$\frac{\#\ \text{molecules}}{N_A} = \#\ \text{moles}$$

$$\#\ \text{moles} \cdot \text{N}_A = \#\ \text{molecules}$$

$$\#\ \text{moles} \cdot \text{MW} = \text{mass}$$

$$\frac{\text{mass}}{\text{MW}} = \#\ \text{moles}$$

$$\frac{\text{mass}}{\#\ \text{moles}} = \text{MW}$$

1 atom is one fundamental unit

1 mole is 6.022×10^{23} fundamental units

Recipe for a reaction

Basic Terminology in Reaction Stoichiometry

- **Mole:** a mole can be thought of as a packet of atoms or molecules (6.022×10^{23} to be exact)
  - We use the "mole" quantity rather than molecules because it is more realistic to work with in a lab.
  - The mass of each element is presented as its **molar mass** on the periodic table (g/mol)
- **Limiting reagent:** the reactant that **runs out first**, thereby forcing the reaction to stop
  - This is important because the number of times you can run a reaction depends on the quantity of the limiting reagent
- **Excess:** a reactant that is added in high quantities so that another reactant(s) run out first
  - This is important because you will have a quantifiable amount of this "excess reagent" left over in the reaction mixture once the limiting reagent runs out

NOTE: to determine the limiting reagent or the reactant(s) in excess, you must consider the ratio between **the amount present** and the **moles required** to run the reaction.

- In other words, the limiting reagent is *not always* the reactant with the least number of moles present in the beginning (we will see an example of this later)

Common Stoichiometry Problems

~~5~~ moles of iron solid reacts with ~~10~~ moles of oxygen gas to form iron(III) oxide solid. Write the balanced chemical equation for this reaction.

$$4\,Fe(s) + 3\,O_2(g) \rightarrow 2\,Fe_2O_3(s)$$

$$\frac{4 \text{ mol } Fe}{rxn} \qquad \frac{3 \text{ mol } O_2}{rxn} \qquad \frac{2 \text{ mol } Fe_2O_3}{rxn}$$

consumed/reacted

produced

Common Stoichiometry Problems

Given the following unbalanced reaction:

$$4\,Fe(s) + 3\,O_2(g) \rightarrow 2\,Fe_2O_3(s)$$

Easy: How many moles of Fe_2O_3 are produced when:

1. 4 moles of iron are reacted with 3 moles of oxygen? 1 rxn, 2 mol Fe_2O_3
2. 8 moles of iron are reacted with 6 moles of oxygen? 2 rxn, 4 mol Fe_2O_3
3. 2 moles of iron are reacted with 1.5 moles of oxygen? ½ rxn, 1 mol Fe_2O_3

Medium: How many moles of oxygen are required to form 5 moles of iron oxide?

$$5 \text{ mol } Fe_2O_3 \times \frac{3 \text{ mol } O_2}{2 \text{ mol } Fe_2O_3} = 7.5 \text{ mol } O_2$$

Difficult: If you have 5 moles of Fe and 10 moles of O_2, identify the limiting reagent and the number of moles of your iron (III) oxide product.

1) Find L.R.

$$Fe: \quad 5 \text{ mol} \times \frac{\text{rxn}}{4 \text{ mol}} = 1.25 \text{ rxn} \rightarrow \text{L.R.}$$

$$O_2: \quad 10 \text{ mol} \times \frac{\text{rxn}}{3 \text{ mol}} = 3.33 \text{ rxn}$$

2) Find products

$$1.25 \text{ rxn} \times \frac{2 \text{ mol } Fe_2O_3}{\text{rxn}} = 2.50 \text{ mol } Fe_2O_3$$

Common Stoichiometry Problem

Given the following unbalanced reaction:

$Fe(s) + O_2(g) \rightarrow Fe_2O_3(s)$

If you have 5 moles of Fe and 10 moles of O_2, identify the limiting reagent and the number of moles of your iron (III) oxide product.

1. Balance the reaction: $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$
2. Solve for the number of reactions you can run with each reactant by comparing the coefficient and the moles you have.
   - You have 5 moles of iron and it takes 4 moles to run one "complete" reaction. Therefore, you can run 1.25 reactions.
   - You have 10 moles of oxygen and it takes 3 moles to rune on "complete" reaction. Therefore, you can run 3.33 reactions.
3. Identify the limiting reagent based on which reactant can run the *least number of reactions* based on the amount present.
   - It should be clear that you will run out of iron first. Therefore, iron is the limiting reagent and you have excess oxygen.
4. Using the number of reactions you can run with the limiting reagent, solve for how many moles of iron (III) oxide are present.
   - We decided we can only run 1.25 reactions. Therefore, we have multiply this times the 2 iron (III) oxide per reaction. This means we end up with 2.5 moles iron(III) oxide.

Stoichiometry: Additional Steps

When studying for exams you should always think: **how can we make these questions more fun** (a.k.a. harder)? Some examples include:

- **Convert your number of moles into mass or weight**
  - Use dimensional analysis to convert from moles to grams to pounds, etc.
- **Account for an experimental percent yield**
  - Simply multiply your final answer by the percent yield
  - For example: in the last problem our answer was 2.50 moles of iron (III) oxide. This represents a 100% **theoretical yield**. If the actual percent yield is 50%, your **experimental yield** is 1.25 moles (2.50 x 0.50).

$$\frac{\text{Experimental Yield}}{\text{Theoretical Yield}} \cdot 100\% = \text{Percent Yield}$$

- **Add a gas law problem at the end (we will cover this later in Unit 1)**
  - For example, use the total volume of gases to solve for the total pressure

Exam-Style Question

Calculate the mass of NH_3 that can be produced from 30.0g of N_2 and 5.0g H_2 in the following unbalanced chemical reaction:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

1. 42.5 g
2. 18.2 g
3. 36.4 g
4. 28.3 g
5. 63.8 g

N_2: $30g \times \frac{mol}{28\ g} = 1.07\ mol$

H_2: $5g \times \frac{mol}{2g} = 2.5\ mol$

Find L.R.

N_2: $1.07\ mol \times \frac{rxn}{1\ mol} = 1.07\ rxn$

H_2: $2.5\ mol \times \frac{rxn}{3\ mol} = 0.833\ rxn$ → L.R.

Find products

$0.833\ rxn \times \frac{2\ mol\ NH_3}{rxn} = 1.67\ mol\ NH_3$

$1.67\ mol\ NH_3 \times \frac{17g}{mol} = 28.3g$

Exam-Style Question

Calculate the mass of NH_3 that can be produced from 30.0g of N_2 and 5.0g H_2 in the following unbalanced chemical reaction:

$$N_2(g) + H_2(g) \rightarrow NH_3(g)$$

1. 42.5 g
2. 18.2 g
3. 36.4 g
4. 28.3 g
5. 63.8 g

Exam-Style Question

A 6.00 mole sample of C_2H_4 at 1.00 atm and 400K is treated with 6.00 moles of oxygen gas at the same temperature and pressure to form carbon dioxide gas and gaseous water. If the reaction goes to completion, what is the total number of moles of all gases at 1.00 atm and 400K?

$$1\,C_2H_4(g) + 3O_2(g) \rightarrow 2H_2O(g) + 2CO_2(g)$$

1. 2.66 moles
2. 12.00 moles
3. 2.00 moles
4. 8.00 moles
5. 6.00 moles

Find L.R.

C_2H_4: $6\text{ mol} \times \frac{\text{rxn}}{1\text{ mol}} = 6\text{ rxn}$ → excess

O_2: $6\text{ mol} \times \frac{\text{rxn}}{3\text{ mol}} = 2\text{ rxn}$ → L.R.

Find products (→ coefficient)

H_2O: $2\text{ rxn} \times \frac{2\text{ mol}}{\text{rxn}} = 4\text{ mol } H_2O$

CO_2: $2\text{ rxn} \times \frac{2\text{ mol}}{\text{rxn}} = 4\text{ mol } CO_2$

Find excess (→ coefficient)

C_2H_4: $6\text{ mol} - \left(2\text{ rxn} \times \frac{1\text{ mol}}{\text{rxn}}\right) = 4\text{ mol } C_2H_4$

6 − 2

moles initial − (moles consumed) = excess

$4\text{ mol } H_2O + 4\text{ mol } CO_2 + 4\text{ mol } C_2H_4 = 12\text{ mol total}$

products + excess = total

Chemistry Fundamentals: Stoichiometry

- Given the following generic, balanced chemical reaction:

$$A_{(g)} + 2B_{(g)} \text{-->} 3C_{(g)} + 4D_{(l)}$$

- **Simple ratio problems:** how many moles of B are required to make 7 moles of C?
  - This problem can be solved by simply understanding the stoichiometric ratio
  - Try for yourself: how many moles of A are required to make 9 moles of D?
- **Limiting Reagent, Gas Law Problems:** what is the total volume of your system when 10 L of A are reacted with 10 L B at STP. Assume this reaction goes to completion.
  - This problem should be solved by working out the reaction
  - ***Do not include condensed states (liquids, solids) in the volume or pressure of the final solution***
    - You will learn why this is true very soon!

Summary of Today

- **What did we learn?**
  - Basic principles of converting between the molecular and molar worlds (micro vs. macro)
  - Basic stoichiometry terminology
  - Examples of stoichiometry problems from easy to advanced

- **How do I master these skills?**
  - Stoichiometry is learned through repetition.
  - Make sure to practice both the easy and difficult examples over and over!
  - After today you should know exactly what to expect from stoichiometry problems on the test. Be able to do these questions on your own without help.