CHE 1301

Basic Principles of Modern Chemistry I

Week 8

Hi! Thanks for checking out the weekly resources for Chemistry 1301! This resource covers topics typically taught by professors during the 8th week of classes.

Visit our website, https://baylor.edu/tutoring, to sign up for appointments and check out additional resources for your course! You'll find helpful links with the following titles:

- "Online Study Guide Resources" – The pace of your course may vary slightly from what's shown in this document. If you don't see the topics you're learning right now, use this link to find the weekly resources for the rest of the semester.
- "How to Participate in Group Tutoring" - See if there is a Chemistry 1301 group tutoring session being hosted this semester. These are weekly question/answer sessions taught by our master tutors!
- "View tutoring times for your course" or "Schedule a private 30-minute appointment!"

You can also give us a call at (254)710-4135, or drop in! Our hours are Monday-Thursday 9 am – 8 pm on class days.

KEY WORDS: Molecular Mass, Mole, Percent Composition, Empirical Formula, Molecular Formula

TOPIC OF THE WEEK: Molecular Mass

What is it? Molecular mass is the mass of one mole of any one type of molecule. For example, the molecular mass of water is the number of grams that a mole of water molecules weighs. More on the meaning of "mole" in Highlight 1!

Calculating MM, aka MW*:

**Molecular Mass is often abbreviated as MW, which stands for Molecular Weight. Weight and mass are different, because weight is a force, and mass is not! But for this purpose, we'll count the two as synonyms.*

Example: C2H6O

1. Use the periodic table to look up the **mass** for each element present. This is the mass of one mole of that element.
    a. C=12.01 g C/mol C
    b. H=1.01 g H/mol H
    c. O=15.99 g O/mol O

2. **Multiply** each element's mass by the number of atoms of that element present in the compound.
    a. 2*12.01=24.02 g C/molecule C_2H_6O
    b. 6*1.01=6.06 g H/molecule C_2H_6O
    c. 1*15.99=15.99 g O/molecule C_2H_6O
3. Add up all of the values from (2).
    a. 24.02 + 6.06 + 15.99 = 46.07 g/molecule C_2H_6O

Highlight 1: The Mole

What is a mole?

A mole is a number. The word "mole" is like the word "dozen" … except instead of meaning twelve, it means 6.02 x 10^23. A mole of atoms is 6.02 x 10^23 atoms. A mole of molecules is 6.02 x 10^23 molecules. A mole of llamas is 6.02 x 10^23 llamas.

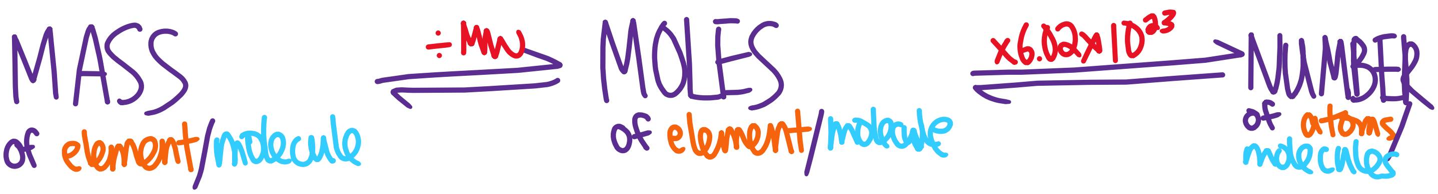
Scientists use the mole when they are referring to a certain number of molecules, as opposed to a certain weight. When reactions happen, a certain number of one type of molecule is combining with a certain number of another:

$$2A + 3B \rightarrow 4C$$

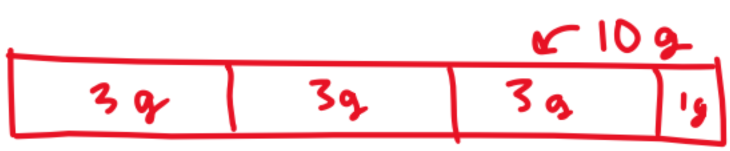
2 As plus 3 Bs yields 4 Cs. If you used 2 moles of A (2 * 6.02 x 10^23 As) and 3 moles of B (3 * 6.02 x 10^23 Bs), then the reaction would happen 6.02 x 10^23 times, using 2 As and 3 Bs each time. In this way, scientists can calculate, quickly, how much of each reagent to use. But if they know how many moles of something they are using, how do they calculate how many grams of it to use?

Well, 1 mole of atoms of an element has the mass, in grams, given on the periodic table. And because of this, 1 mole of molecules has a mass, in grams, called molecular mass—see the Topic of the Week!

Here is a diagram that represents the ways to convert between mass, moles, and number of molecules:



This next diagram shows why dividing by molecular weight converts from mass to moles:



The biggest rectangle represents 10 grams of a substance. Let's say that we know that one mole of the substance weighs 3 grams. How could we calculate the number of moles in 10 grams? Divide 10 grams (the total mass) by the molecular mass (3 grams). 10 g = 3.33 mol

Try the first 3 problems at the end of the document to make sure that this is clicking! Then, take a look at the next two sections.

Highlight 2: Percent composition

Percent composition answers this question: How much (mass-wise) of the formula is [insert element name here]?

Ex. NH_3

How to calculate:

1. Find the mass of the whole compound (see Topic of the Week: Molecular Mass)
    a. MW of NH_3: 17.03 g/mol. Try calculating it!
2. Find the mass of just [insert element name here] (in this compound)
    a. Find the mass of the element on the periodic table
        i. N weighs 14.01 g
        ii. H weighs 1.01 g
    b. Multiply it by the number of atoms of this element that are in this molecule
        i. N: 14.01 * 1 = 14.01 g
        ii. H: 1.01 * 3 = 3.03 g
3. Divide the mass of just [insert element name here] by the mass of the whole compound. Multiply your answer by 100 to get the percent.
    a. N: (14.01 g / 17.03 g) * 100 = 82.24%
    b. H: (3.03 g / 17.03 g) * 100 = 17.76%

Highlight 3: Periodic Trends

Ex. 24.3% C, 4.1% H, 74.6% Cl

1. **Determining Empirical Formula [Given Percent Composition]**
    a. What is empirical formula? It's the formula of a compound with the lowest ratios.
    b. Use the percentage to assign a mass value to each element. You **can assume any total mass**, as long as you assume the same total mass for everything. This is because we are going to be working with ratios. I usually assume 100 grams because it makes calculations easy! Multiply your percentage by the total mass to get the mass of each element.
        i. 24.3% C * 100 g = 24.3 g C
        ii. 4.1% H * 100 g = 4.1 g H
        iii. 74.6% Cl * 100 g = 74.6 g Cl

iv. *If you're given masses of each compound instead of percentages, you can skip to step B!*

c. Convert grams of each substance to moles. (See Highlight 1)

i. 24.3 g C * (1 mol C / 12.01 g C) = 2.03 mol C

ii. 4.1 g H * (1 mol H / 1.01 g H) = 4.06 mol H

iii. 74.6 g Cl * (1 mol Cl / 35.45 g Cl) = 2.10 mol Cl

d. Divide each number of moles by the *lowest number of moles* to get mole ratios.

i. 2.03 mol C / 2.03 mol C = 1 mol C per mol of C

ii. 4.06 mol H / 2.03 mol C = about 2 mol H per mol of C

iii. 2.10 mol Cl / 2.03 mol C = about 1 mol Cl per mol of C

e. Write empirical formula according to mole ratios (needn't write out "1")

i. CH_2Cl

2. Determining Molecular Formula (Given Empirical Formula and Molecular Mass)

Ex. CH_2Cl, 99 g

a. Add up the weights of all the atoms in the empirical formula. *If this formula applied to the whole molecule, what would the molecular mass be?*

i. 49.48 g

b. *What number could you multiply by the empirical formula's mass to get the molecular mass?* Mass of empirical formula x [constant] = mass of molecular formula

i. 49.48 g * 2 = 98.96 ≈ 99

c. Multiply each of the empirical formula's subscripts by that number.

i. $C_2H_4Cl_2$

Check Your Understanding

1. How many moles of SO_4 are in 1 mol $(NH_4)_2SO_4$? How many moles of NH_4?
2. What is the mass of 3 moles of $Ca(NO_3)_2$? Hint: Start by calculating molecular mass.
3. Consider the following: 1 mol Br_2, 1 mol O_2, 1 mol Cl_2
   a. Which has the largest number of molecules?
   b. Which has the largest mass?

Things You May Struggle With

- A mole of molecules is 6.02 * 10^23 molecules, even though there are more than 6.02 * 10^23 atoms. Remember: a mole is a number!
- What is the difference between empirical and molecular formulas? The empirical formula shows the ratios between numbers of elements. Only an empirical formula can be calculated based on percent composition, because percentages show relative amounts, not absolute amounts. But if

given the molecular mass, this knowledge can be combined with that of the ratios to figure out the molecular formula (see Highlight 3).

That's all this week! Please reach out if you have any questions and don't forget to visit the Tutoring Center website for further information at www.baylor.edu/tutoring. Answers to Check Your Learning are below.

1. 1 mol SO_4, 2 mol NH_4
2. 3 mol * 164.086 g/mol = 492.258 g
3.
    a. They all have the same number of molecules! 1 mol is 6.022*10^23 molecules no matter what
    b. 1 mol of Br_2 is the heaviest, because each Br_2 is heavier than each Cl_2 or O_2 (it has the highest molecular mass).