

# UNIT 3 – CHAPTER 3 STUDENT NOTES: STOICHIOMETRY

## Counting Atoms:

A rubber stopper weighs 3.26 grams and a cork stopper weighs 2.18 grams.

- How many rubber stoppers are there in 88.02 grams of rubber stoppers?
- How many cork stoppers are there in 85.02 grams of cork stoppers?
- What mass of cork stoppers would have to be weighed out to get the same number of cork stoppers that would be in 185.82 grams of rubber stoppers?

## The mole:

Molar mass  $\longleftrightarrow$  Mole  $\longleftrightarrow$  Particles

Terms: Mole – Amount of a substance  $\xrightarrow{6.02 \times 10^{23}}$  PARTICLES  
 $\xrightarrow{\text{MASS (g)}}$   
 $\xrightarrow{\text{VOLUME OF GAS @ STP (L)}}$

Molar mass – MASS of 1 MOLE of a substance

Atomic weight – WEIGHTED AVERAGE OF ATOMS OF AN ELEMENT (CONSIDERING ISOTOPES)

## Calculate:

- 2.27 grams of  $N_2$  = \_\_\_\_\_ moles
- 0.030 moles of  $N_2$  = \_\_\_\_\_ grams
- 0.72 grams of  $N_2$  = \_\_\_\_\_ particles
- $3.00 \times 10^{20}$  molecules of  $N_2$  = \_\_\_\_\_ grams

**Calculate:** Aspartame  $C_{14}H_{18}N_2O_5$

a) molar mass of aspartame

$$\begin{array}{ccccccc} C(14 \times 12) & H(18 \times 1) & N(2 \times 14) & O(5 \times 16) & & & \\ 168 & + & 18 & + & 28 & + & 80 = 294 \text{ g/mol} \end{array}$$

b) moles in 10.0 grams aspartame

$$10.0 \text{ g ASP} \times \frac{1 \text{ mol ASP}}{294 \text{ g ASP}} = 0.0340 \text{ mol ASP}$$

c) grams of 1.56 moles of aspartame

$$1.56 \text{ mol ASP} \times \frac{294 \text{ g ASP}}{1 \text{ mol ASP}} = 459 \text{ g ASP}$$

d) particles in 5.0 milligrams of aspartame

$$5.0 \text{ mg ASP} \times \frac{1 \text{ g ASP}}{1000 \text{ mg ASP}} \times \frac{1 \text{ mol ASP}}{294 \text{ g ASP}} \times 6.02 \times 10^{23} \text{ PARTICLES ASP} = 1.0 \times 10^{19} \text{ PARTICLES ASP}$$

e) atoms of N in 1.2 grams of aspartame

$$1.2 \text{ g ASP} \times \frac{1 \text{ mol ASP}}{294 \text{ g ASP}} \times 6.02 \times 10^{23} \text{ PARTICLES ASP} \times \frac{2 \text{ ATOMS N}}{1 \text{ PARTICLE ASP}} = 4.9 \times 10^{21} \text{ ATOMS N}$$

f) grams in  $1.0 \times 10^9$  molecules of aspartame

$$1.0 \times 10^9 \text{ MOLEC. ASP} \times \frac{1 \text{ mol ASP}}{6.02 \times 10^{23} \text{ MOLEC. ASP}} \times \frac{294 \text{ g ASP}}{1 \text{ mol ASP}} = 4.9 \times 10^{-13} \text{ g ASP}$$

g) mass, in grams, of 1 molecule of aspartame

$$1 \text{ MOLEC. ASP} \times \frac{1 \text{ mol ASP}}{6.02 \times 10^{23} \text{ MOLEC. ASP}} \times \frac{294 \text{ g ASP}}{1 \text{ mol ASP}} = 4.89 \times 10^{-22} \text{ g ASP} \rightarrow 5 \times 10^{-22} \text{ g ASP}$$

### Atomic weight

A class of ten students take a quiz in AP Chemistry. In this class, 9 students get a 90% and 1 student gets a 50%. What is the average score for this quiz?

Calculate the atomic weight of Mg from the following information:

| Isotope | % Abundance | Atomic Mass (AMU) |
|---------|-------------|-------------------|
| Mg-24   | 78.99%      | 23.9850           |
| Mg-25   | 10.00%      | 24.9858           |
| Mg-26   | 11.01%      | 25.9826           |

The average atomic mass of naturally occurring neon is 20.18 amu. There are two common isotopes of naturally occurring neon as indicated by the table below. i) Calculate the percent abundance of each isotope. ii) Calculate the number of Ne-22 atoms in a 12.55 g sample of naturally occurring neon.

| Isotope | Mass (AMU) |
|---------|------------|
| Ne-20   | 19.99      |
| Ne-22   | 21.99      |

# Determining empirical and molecular formula

Empirical formula: **ATOMS IN THE LOWEST WHOLE-NUMBER RATIO**

Molecular formula: **FORMULA OF A MOLECULE (ACTUAL IDENTITY)**

EX 1: C – 38.6g

H – 16.22g

N – 45.11g

Molar mass of caffeine: 194.2g/mole

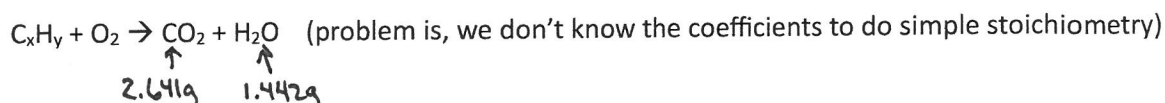
C: 49.58%

H: 5.15%

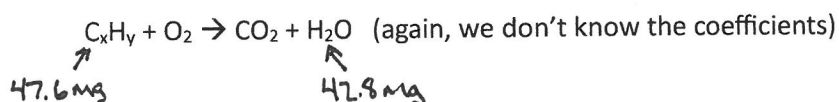
N: 28.87%

O: 16.40%

1. Many homes in rural America are heated by propane gas, a compound that contains only carbon and hydrogen. Complete combustion of a sample of propane produced 2.641 g of carbon dioxide and 1.442 g of water as the only products. Find the empirical formula of propane.

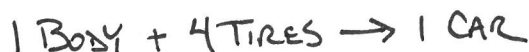


2. Cumene is a compound containing only carbon and hydrogen that is used in the production of acetone and phenol in the chemical industry. Combustion of 47.6 mg cumene produces some  $\text{CO}_2$  and 42.8 mg of  $\text{H}_2\text{O}$ . The molar mass of cumene is between 115 and 125 g/mol. What are the empirical and molecular formulas of cumene?



# Stoichiometry

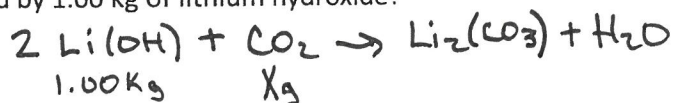
In the construction of a car, 1 body plus 4 tires will make 1 car. If 1 body weighs 1250 lbs, 1 tire weighs 45 lbs, and 1 car weighs 1430 lbs, answer the following questions:



- the number of cars that can be made with 900 lbs of tires.
- the mass of cars that can be built with 900 lbs of tires.
- the pounds of tires needed if 8750 lbs of bodies are used to build cars.
- the pounds of cars that can be made if 18750 lbs of bodies and 1980 lbs of tires are used to build cars.

## Stoichiometry problems note sheet

1. Solid lithium hydroxide is used in space vehicles to remove exhaled carbon dioxide from the living environment by forming solid lithium carbonate and liquid water. What mass of gaseous carbon dioxide can be absorbed by 1.00 kg of lithium hydroxide?



$$1 \text{ Li} \times 6.941 = 6.941$$

$$1 \text{ O} \times 16 = 16$$

$$1 \text{ H} \times 1.0079 = 1.0079$$

$$\underline{23.952}$$

$$\text{Li(OH)}$$

$$1 \text{ C} \times 12 = 12$$

$$2 \text{ O} \times 16 = 32$$

$$\underline{44 \text{ g}}$$

$$\text{CO}_2$$

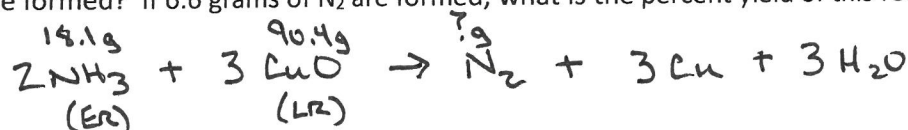
$$\frac{1.00 \text{ kg Li(OH)}}{1 \text{ kg Li(OH)}} \times \frac{1000 \text{ g Li(OH)}}{23.95 \text{ g Li(OH)}} \times \frac{1 \text{ mol Li(OH)}}{23.95 \text{ g Li(OH)}} \times \frac{1 \text{ mol CO}_2}{2 \text{ mol Li(OH)}} \times \frac{44 \text{ g CO}_2}{1 \text{ mol CO}_2}$$

$$= 918.58 \text{ g CO}_2 = \boxed{919 \text{ g}}$$

2. With homecoming around the corner, students will be looking to get dates to go to the dance. If a particular class is composed of 9375 lbs of girls (average weight 125 lbs) and 14760 lbs of boys (average weight 180 lbs): a) What is the maximum number of couples that can be made to go the dance and b) How much excess will be left over?

3. You have 130 g of zinc and 100 g of hydrogen chloride. Calculate a) the amount of zinc chloride that is produced in this reaction and b) the amount of excess remaining.

4. Nitrogen gas can be prepared by passing gaseous ammonia over solid copper (II) oxide at a high temperature. The other products of the reaction are solid copper and water vapor. If a sample containing 18.1 g of  $\text{NH}_3$  is reacted with 90.4 g of  $\text{CuO}$ , which is the limiting reagent? How many grams of  $\text{N}_2$  will be formed? If 6.6 grams of  $\text{N}_2$  are formed, what is the percent yield of this reaction?



$$\text{IF NH}_3: 18.1\text{g NH}_3 \left| \frac{1\text{mol NH}_3}{17.03\text{g NH}_3} \right| \frac{1\text{mol N}_2}{2\text{mol NH}_3} \left| \frac{28.0\text{g N}_2}{1\text{mol N}_2} \right| = 14.88\text{g N}_2$$

$$\text{IF CuO: } 90.4\text{g CuO} \left| \frac{1\text{mol CuO}}{79.55\text{g CuO}} \right| \frac{1\text{mol N}_2}{3\text{mol CuO}} \left| \frac{28.0\text{g N}_2}{1\text{mol N}_2} \right| = 10.6\text{g N}_2$$

$$\text{THEORETICAL YIELD} = 10.6\text{g N}_2$$

$$\text{ACTUAL YIELD} = 6.6\text{g N}_2$$

$$\% \text{ YIELD} = \frac{\text{ACTUAL}}{\text{THEORETICAL}} \times 100\% \rightarrow \frac{6.6\text{g}}{10.6\text{g}} \times 100\% = 62.5\%$$

**Hydrates:** Ionic compounds often separate from water solution with molecules of water incorporated into the solid. Such compounds are referred to as **hydrates**. Certain hydrates lose all or part of their water of hydration when exposed to dry air or are heated. This process is referred to as **efflorescence**. Frequently, dehydration is accompanied by color change. Crystals of the hydrate  $\text{CoCl}_2 \cdot 6 \text{H}_2\text{O}$  change from red to purple in dry air or when heated and are used as humidity indicators and as an ingredient of invisible ink. Writing only becomes visible when the paper is heated, driving the water out and leaving a blue residue.

Hydrates are named by the number of waters attached to the anhydrous compound, using the following prefixes:

|           |           |
|-----------|-----------|
| 1 – mono  | 6 – hex   |
| 2 – di    | 7 – hept  |
| 3 – tri   | 8 – oct   |
| 4 – tetra | 9 – non   |
| 5 – pent  | 10 – deca |

Name the following hydrates:



EX 2: A certain hydrate of potassium aluminum sulfate (alum) has a formula of  $\text{KAl}(\text{SO}_4)_2 \cdot X \text{H}_2\text{O}$ . When a hydrate sample weighing 5.459 g is heated to remove all water, 2.583 g of  $\text{KAl}(\text{SO}_4)_2$  remains. What is the mass percent of water in the hydrate? What is the empirical formula?

$$\begin{array}{r} 5.459 \text{ g Hydrated Alum} \\ - 2.583 \text{ g Anhydrous Alum} \\ \hline 2.876 \text{ g H}_2\text{O} \end{array}$$

EX 2: Epsom salts are hydrates of magnesium sulfate. The name of Epsom salts is magnesium sulfate heptahydrate. A 7.834 g sample is heated until a constant mass is obtained, indicating that all the water has been evaporated off. 1) What is the formula for Epsom salts, 2) what is the mass of the anhydrous magnesium sulfate, and 3) what is the percentage of the hydrate (water)?

$$1) \boxed{\text{MgSO}_4 \cdot 7 \text{H}_2\text{O}} = 246.37$$

$$120.37 + (7 \times 18)$$

$$3) \% \text{H}_2\text{O} = \frac{7 \times 18}{246.37 \text{ g molar}} = \frac{126 \text{ g H}_2\text{O}}{246.37 \text{ g molar}} = 51.1\% \text{ H}_2\text{O}$$

$$100\% - 51.1\% = 48.8\% \text{ MgSO}_4$$

$$2) 7.834 \text{ g SAMPLE} \times 48.8\% = \boxed{3.823 \text{ g MgSO}_4}$$