

Monday/Tuesday, October 14 & 15, 2019 - Stoichiometry (Chapter 3) Part 2

I. Warm-Up

- How many significant figures does 0.000123045560 have? **9**
- $12.5849 / 2.4 = 5.2$
- $432.5 - 24.3984 = 408.1$
- $12.0(11.90 - 11.8) = 133.$
- $\frac{1.203 \times 10^6}{0.000360 - 2.40 \times 10^5} = -5.01$

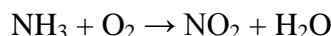
Significant Figures Rules

Addition/Subtraction – The answer is precise as the least accurate number

Multiplication/Division – The answer has the same sig figs as the number with the least sig. figs.

II. Limiting Reagents and Theoretical Yields

- Consider the following unbalanced reaction – assume the reaction goes to completion in each scenario:



- How many moles of oxygen gas are required to make 12.8 moles of nitrogen dioxide? **22.4 mol O₂**

1st balance the reaction $\Rightarrow 4 \text{NH}_3 + 7 \text{O}_2 \rightarrow 4 \text{NO}_2 + 6 \text{H}_2\text{O}$

$$12.8 \text{ mol NO}_2 \times \frac{7 \text{ mol O}_2}{4 \text{ mol N O}_2} = 22.4 \text{ mol O}_2$$

- How many grams of water can be produced from 9.64 g of ammonia?

$$9.64 \text{ NH}_3 \times \frac{1 \text{ mol NH}_3}{17.034 \text{ g}} \times \frac{6 \text{ mol H}_2\text{O}}{4 \text{ mol NH}_3} \times \frac{18.016 \text{ g H}_2\text{O}}{1 \text{ mol H}_2\text{O}} = 15.3 \text{ g H}_2\text{O}$$

- Identify the limiting reagent if 3 moles of ammonia is combined with 5 moles of oxygen. **O₂ is LR**

$$3 \frac{\text{mol NH}_3}{4} = 0.75 \quad \text{vs.} \quad \frac{5 \text{ mol O}_2}{7} = 0.71 \Rightarrow \text{smaller so O}_2 \text{ is the LR}$$

- Identify the limiting reagent if 10.00 g of ammonia is combined with 28.00 g of oxygen. **O₂ is the LR**

$$10 \text{ g NH}_3 \times \frac{1 \text{ mol NH}_3}{17.034 \text{ g}} = 0.587 \text{ mol NH}_3 \Rightarrow \frac{0.587 \text{ mol NH}_3}{4} = 0.15 \text{ vs.}$$

$$28 \text{ g O}_2 \times \frac{1 \text{ mol O}_2}{16 \text{ g}} = 0.875 \text{ mol O}_2 \Rightarrow \frac{0.875 \text{ mol O}_2}{7} = 0.12 \Rightarrow \text{smaller so O}_2 \text{ is the LR}$$

- How many grams of each species will be present if 10.00 g of ammonia is combined with 28.00 g oxygen?

Since O₂ is the LR there will be none of it left and O₂ will determine the answer for all the remaining species

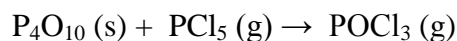
$$\text{NH}_3 \Rightarrow 0.875 \text{ mol O}_2 \times \frac{4 \text{ mol NH}_3}{7 \text{ mol O}_2} \times \frac{17.034 \text{ g}}{1 \text{ mol NH}_3} = 8.5 \text{ g of NH}_3 \text{ is consumed} \Rightarrow 10 \text{ g} - 8.5 \text{ g} = 1.5 \text{ g NH}_3 \text{ remains}$$

$$\text{NO}_2 \Rightarrow 0.875 \text{ mol O}_2 \times \frac{4 \text{ mol NO}_2}{7 \text{ mol O}_2} \times \frac{46.01 \text{ g}}{1 \text{ mol NO}_2} = 23 \text{ g of NO}_2 \text{ is made}$$

$$\text{H}_2\text{O} \Rightarrow 0.875 \text{ mol O}_2 \times \frac{6 \text{ mol H}_2\text{O}}{7 \text{ mol O}_2} \times \frac{18.016 \text{ g}}{1 \text{ mol H}_2\text{O}} = 13.5 \text{ g of H}_2\text{O} \text{ is made}$$

Also try doing the ICF Table method.

2. Consider the following unbalanced reaction:



When 35 g of solid P_4O_{10} and 42 g of gaseous PCl_5 is combined 47 g of POCl_3 is produced. What is the percent yield for this process?



ID the LR $\Rightarrow 35 \text{ g P}_4\text{O}_{10} \times \frac{1 \text{ mole}}{283.88 \text{ g}} = 0.1233 \text{ mol} \Rightarrow \frac{0.1233 \text{ mol}}{1} = 0.1233 \text{ vs.}$

$42 \text{ g PCl}_5 \times \frac{1 \text{ mole}}{208.22 \text{ g}} = 0.202 \text{ mol} \Rightarrow \frac{0.202 \text{ mol}}{6} = 0.0337 \Rightarrow$ smaller so PCl_5 is the LR

Theoretical yield $\Rightarrow 0.202 \text{ mol PCl}_5 \times \frac{10 \text{ mol POCl}_3}{6 \text{ mol PCl}_5} \times \frac{153.32 \text{ g POCl}_3}{1 \text{ mol POCl}_3} = 51.62 \text{ g POCl}_3$

Percent Yield $= \frac{47 \text{ g}}{51.62 \text{ g}} \times 100 = 91 \%$

III. Composition of Compounds

Recall: Law of Def. & Multiple Prop.

3. Calculate the mass percent of Cl in NaCl.

$35.5 \text{ g Cl} / (35.5 \text{ g} + 23 \text{ g}) \text{ NaCl} = 61\% \text{ Cl}$

4. A 1.40 g sample of silicon reacts with fluorine to produce 5.2 g of a product. What is the empirical formula of the compound?



By conservation of mass, $5.2 \text{ g} - 1.4 \text{ g} = x = 3.8 \text{ g}$

Convert the grams to moles of substance:

$1.4 \text{ g Si} \times \frac{1 \text{ mol Si}}{28 \text{ g Si}} = 0.05 \text{ mol Si}; 3.8 \text{ g F}_2 \times \frac{2 \text{ mol F}}{38 \text{ g F}_2} = 0.2 \text{ mol F}$

Divide for ratio $0.05 \Rightarrow 1 \text{ mol Si}; 4 \text{ mol F} \Rightarrow \text{EF} = \text{SiF}_4$

5. The empirical formula for xylene is C_4H_5 and xylene has a molar mass of 106.16 g/mol. Determine the molecular formula for xylene.

$\text{Molar Mass}(\text{given}) / \text{Molar Mass}(\text{EF}) = 106.16 \text{ g/mol} / 53.08 \text{ g/mol} = 2$. Double the empirical formula $\Rightarrow \text{C}_8\text{H}_{10}$

6. An alkali metal oxide contains 83.01% metal by mass. Determine the identity of the metal.

Alkali metal is group 1 \Rightarrow so Ca and Zn are not possible \Rightarrow Group 1 are 1+ in ionic compounds and oxides are 2- \Rightarrow an alkali metal oxide will have the formula $\Rightarrow \text{M}_2\text{O}$

$83.01\% = \frac{2M}{2M+16} \times 100 \Rightarrow M \text{ is } 39.1 \text{ g/mol} \Rightarrow \text{K}$

Empirical Formula—Tells the ratio of atoms of each element present in the compound.
e.g. $-\text{CH}_2\text{O}$ is the empirical formula

1. Convert given values into moles for each element
2. Divide all moles by the smallest mole value
3. If you have all whole numbers you have the EF – if not try multiplying them all by 2 or 3 etc.

Molecular Formula – Tells the actual numbers of atoms of each element in a molecule.
e.g. $-\text{C}_6\text{H}_{12}\text{O}_6$ is the molecular formula of glucose

1. Derive empirical formula
2. Determine the empirical mass
3. $\frac{(\text{Molar mass})}{(\text{empirical mass})} = \text{multiple}$
4. Multiply the empirical formula by the multiple

7. Tryptophan is an amino acid that is 64.7% carbon, 5.9% hydrogen, 13.7% nitrogen and 15.7% oxygen. What is the empirical formula for tryptophan?

If you have 100 g sample of tryptophan \Rightarrow 64.7 g C : 5.9 g H : 13.7 g N : 15.7 g O

$$\frac{64.7 \text{ g C}}{12.01 \frac{\text{g}}{\text{mol}}} : \frac{5.9 \text{ g H}}{1.008 \frac{\text{g}}{\text{mol}}} : \frac{13.7 \text{ g N}}{14.01 \frac{\text{g}}{\text{mol}}} : \frac{15.7 \text{ g O}}{16 \frac{\text{g}}{\text{mol}}}$$

$$5.387 \text{ mol C} : 5.853 \text{ mol H} : 0.9779 \text{ mol N} : 0.9812 \text{ mol O}$$

divide each by the smallest ratio (0.9779)

$$5.5 \text{ mol C} : 6 \text{ mol H} : 1 \text{ mol N} : 1 \text{ mol O}$$

double each to get the Empirical Formula



8. **The Combustion Problem** - A 0.4647-g sample of a compound known to contain only carbon, hydrogen, and oxygen was burned in oxygen to yield 0.8635 g of CO_2 and 0.1767 g of H_2O . If the molar mass is 213 g/mol, what is the molecular formula of the compound?

$\text{C}_x\text{H}_y\text{O}_z + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \Rightarrow$ all of the C ends up in the CO_2 and all of the H ends up in the H_2O
the O is not so obvious

$$\text{C} \Rightarrow \frac{12.01 \text{ g C}}{44.01 \text{ g CO}_2} = \frac{x \text{ g C}}{0.8635 \text{ g CO}_2} \Rightarrow 0.2356 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.01962 \text{ mol C}$$

$$\text{H} \Rightarrow \frac{2.016 \text{ g C}}{18.016 \text{ g H}_2\text{O}} = \frac{x \text{ g H}}{0.1767 \text{ g H}_2\text{O}} \Rightarrow 0.01977 \text{ g H} \times \frac{1 \text{ mol H}}{1.008 \text{ g H}} = 0.01961 \text{ mol H}$$

$$\text{O} \Rightarrow 0.4647 \text{ g cmpd} - 0.2356 \text{ g C} - 0.01977 \text{ g H} = 0.2093 \text{ g O} \times \frac{1 \text{ mol O}}{16 \text{ g O}} = 0.01308 \text{ mol O}$$

divide each by the smallest (0.01308)

$$1.5 \text{ mol C} : 1.5 \text{ mol H} : 1 \text{ mol O}$$

double each $\Rightarrow \text{C}_3\text{H}_3\text{O}_2 \Rightarrow \text{MW} = 71 \text{ g/mol}$

$$(213 \text{ g/mol}) / (71 \text{ g/mol}) = 3 \Rightarrow \text{MF C}_9\text{H}_9\text{O}_6$$

9. **Hmm...** Two compounds contain the same metal and oxygen. Compound I has 13.38% oxygen and Compound 2 has 9.334% oxygen.

a. Calculate the mass of oxygen per 1.000 g of metal.

Assuming 1.00g of metal, Compound I - 0.1338g of oxygen; Compound II - 0.09334g of oxygen

b. If the first compound is MO_2 what is the formula of the second compound?

By law of MP, the second compound has 2/3 as much oxygen, so the formula is $\text{MO}_{4/3} = \text{M}_3\text{O}_4$

c. Name the metal.

Looking at the mass of metal for 1 mol, the metal is most likely lead (Pb).