Chapter 9

STOICHIOMETRY

Section 9.1: Introduction to Stoichiometry

- Stoichiometry: the calculation of quantities in chemical equations
- From Greek:
  - "Stoikheion" = element
  - "Metron" = to measure
- It's the bookkeeping of chemistry!

Stoichiometry

There are two types of Stoichiometry

Composition Stoichiometry

The mass relationships of elements in compounds

$NaCl$ and H_3PO_4

Reaction Stoichiometry

The mass relationships of reactants and products in a chemical reaction

$$2\ H_2 + O_2 \rightarrow 2H_2O$$

Chemical Equations

All balanced equations are always based on the units of the <u>mole</u>

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

Translated:

$$1\ \text{mol}\ N_2 + 3\ \text{mol}\ H_2 \rightarrow 2\ \text{mol}\ NH_3$$

Mrs. Agostine's Lemonade

1 glass of bottled water (8 oz.)

4 lemons

¼ cup sugar

4 ice cubes

Squeeze lemons into water. Add sugar to lemon water. Add ice cubes. Stir. Makes one glass of lemonade.

Mrs. Agostine's Lemonade

1 glass of water (8 oz.)
4 lemons
¼ cup sugar
4 ice cubes

Squeeze lemons into water. Add sugar to lemon water. Add ice cubes. Stir.

How many glasses of lemonade can you make if you have 20 lemons, 10 cups sugar and an unlimited amount of water and ice cubes?

Mrs. Agostine's Lemonade

1 glass of water (8 oz.)
4 lemons
¼ cup sugar
4 ice cubes

Squeeze lemons into water. Add sugar to lemon water. Add ice cubes. Stir.

- Will there be any leftover ingredients (not including the water or ice cubes)?
- How much will be left over?

Mole Ratio

- The mole ratio is a conversion factor that relates the number of moles of any two substances involved in a chemical reaction.
- The information comes directly from the balanced chemical equation for the reaction.

Five Types of Reaction Stoichiometry Problems

Section 9.2: Stoichiometric Calculations

Types of Equations

1. Mole-Mole
2. Mass-Mass
3. Volume-Volume
4. Particle-Particle
5. Mixed Problems

Stoichiometry Problems

1. Mole-Mole Problems

$$\text{moles of A} \longrightarrow \text{moles B}$$

MOLE RATIO

MOLES OF A	MOLE RATIO	MOLES OF B
A	$\frac{B}{A}$	B

Stoichiometry Problems

2. Volume-Volume Problems

volume A $\rightarrow$ moles A $\rightarrow$ moles B $\rightarrow$ volume B

Volume - Volume Problems

volume of A	**moles of A**	**MOLE RATIO**	**moles of B**	**volume of B**
→	→	→	→	→

Stoichiometry Problems

3. Mass-Mass Problems

$$\text{mass A} \rightarrow \text{moles A} \rightarrow \text{moles B} \rightarrow \text{mass B}$$

Mass to Mass Problems

grams of A	moles of A	MOLE RATIO	moles of B	grams of B
→	→	→	→	→

Stoichiometry Problems

4. Particle-Particle Problems

particles A $\rightarrow$ moles A $\rightarrow$ moles B $\rightarrow$ particles B

Particle - Particle Problems

particles of A	moles of A	MOLE RATIO	moles of B	particles of B
→	→	→	→	→

Stoichiometry Problems

5. ## Mixed-Mole Problems

? unit A $\rightarrow$ moles A $\rightarrow$ moles B $\rightarrow$?unit B

Mixed Problems

? unit of A	moles of A	MOLE RATIO	moles of B	? unit of B
→	→	→	→	→

Sect. 9.3: Limiting Reagent & Percent Yield

- Limiting Reagent: the reactant that limits the amount of products made
  - Gets completely used up in a reaction
- Excess Reagent: the reactant that is not used up completely
  - There is more then enough leftover

Limiting & Excess Reagent

<u>Steps to determine LR & ER</u>

1. Set up two mass-mass problems.
2. See how much of one reactant is left <u>if</u> the other is used up completely.
3. <u>Then</u> determine the limiting reagent. Use it to determine how much product is made in a mass-mass problem.

Limiting & Excess Reagents

$$C + O_2 \rightarrow CO_2$$

If 35 g of oxygen and 55 g of carbon are available, which is the limiting reagent? What mass of carbon dioxide is produced?

Limiting & Excess Reagent

$$C + O_2 \rightarrow CO_2$$

If $55 \text{ g C} \times \frac{1 \text{ mol C}}{12 \text{ g C}} \times \frac{1 \text{ mol } O_2}{1 \text{ mol C}} \times \frac{32 \text{ g } O_2}{1 \text{ mol } O_2} =$

$= 146.67 \text{ g } O_2$ needed

(is that provided in the problem?)

If $35 \text{ g } O_2 \times \frac{1 \text{ mol } O_2}{32 \text{ g } O_2} \times \frac{1 \text{ mol C}}{1 \text{ mol } O_2} \times \frac{12 \text{ g C}}{1 \text{ mol C}} =$

$= 13.13 \text{ g C}$ needed

(is that provided in the problem?)

Limiting & Excess Reagent

If $55\ g\ C \times \frac{1\ mol\ C}{12\ g\ C} \times \frac{1\ mol\ O_2}{1\ mol\ C} \times \frac{32\ g\ O_2}{1\ mol\ O_2} =$

$= 146.67\ g\ O_2$ needed

(is that provided in the problem?)

No, only 35 g O_2 provided- C cannot be LR

If $35\ g\ O_2 \times \frac{1\ mol\ O_2}{32\ g\ O_2} \times \frac{1\ mol\ C}{1\ mol\ O_2} \times \frac{12\ g\ C}{1\ mol\ C} =$

$= 13.13\ g\ C$ needed

(is that provided in the problem?)

Yes! We have 55 g C provided and the O_2 gets used up as the limiting reagent!

Limiting & Excess Reagent

How much of the carbon is leftover?

55 g C (given in the problem)

- 13.13 g C (used in the problem)

41.87 g C leftover in EXCESS!

Limiting & Excess Reagent

- If O_2 is the limiting reagent then it is used up completely and determines how much of the product is made!

Then $35\ g\ O_2 \times \frac{1\ mol\ O_2}{32\ g\ O_2} \times \frac{1\ mol\ CO_2}{1\ mol\ O_2} \times \frac{44.01\ g\ CO_2}{1\ mol\ CO_2} =$

$= 48.14\ g\ CO_2$ produced

Percent Yield

- Used to determine how accurate a person is in the laboratory.

$$\% \, Yield = \frac{Experimental\, Yield}{Theoretical\, Yield} \times 100$$

<u>Experimental Yield</u>: the amount of product that actually forms in the lab

<u>Theoretical Yield</u>: the amount that should be made in theory in the lab

Percent Yield

- What is the percent yield if John made 15.87 g of chalk and he calculated he should make 22.5 grams of chalk?

% Yield Calculation

- $$\% \, Yield = \frac{Experimental\, Yield}{Theoretical\, Yield} \times 100$$

$$\% \text{ Yield} = \frac{15.87\ g}{22.5\ g} \times 100$$

$$\% \text{ Yield} = 70.5\ \%$$