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?

You can only make 5 glasses 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.

- Will there be any leftover ingredients (not including the water or ice cubes)?
- How much will be left over?
- There will be 8 ¾ cups sugar left.

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. Mole – Mass or Mass - Mole
3. Mass-Mass
4. Volume-Volume
5. Particle-Particle
6. 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
mol A	$\frac{\text{mol B}}{\text{mol A}}$	mol B

Stoichiometry Problems

2. Moles-Mass Problems

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

Mole to Mass Problems

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

Stoichiometry Problems

3. Mass-Moles Problems

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

Mass to Mole Problems

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

Stoichiometry Problems

4. 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

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
→	→	→	→	→

Volume - Volume Problems at STP

If both compounds are gas phase and at STP:

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

Stoichiometry Problems

4. Particle-Particle Problems

particles A → moles A → moles B → 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 → moles A → moles B → ?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 Limiting & Excess Reagents</u>

1. Set up two mass-mass problems.
2. Determine how many grams (moles) of product that you can make from each reactant.
3. The reactant that makes less product is the limiting reagent. The other reactant is the excess reagent.
4. The most product you can make is the lesser amount.

How Much Excess Reagent Is Left?

<u>Steps To Determine How Much Excess Reagent</u>

1. Set up a mass to mass problem between the two reactants.
2. Calculate how many grams of the excess reagent is used when all of the limiting reagent is used.
3. Subtract the amount of excess reagent used from the amount given in the problem.
4. That amount is the excess of that reagent.

Limiting & Excess Reagents

$$C + O_2 \rightarrow CO_2$$

If 35.0 g of oxygen and 55.0 g of carbon are available, which is the limiting reagent? What mass of carbon dioxide is produced?

Limiting & Excess Reagent

$$C + O_2 \rightarrow CO_2$$

Starting with the Carbon, calculate how much CO_2 will be produced:

$$55.0 g\ C \times \frac{1\ mole\ C}{12.01\ g\ C} \times \frac{1\ mole\ CO_2}{1\ mole\ C} \times \frac{44.01\ g\ CO_2}{1\ mole\ CO_2} = 201.5\ g\ CO_2$$

Next calculate how much CO_2 will be produced from the O_2:

$$35.0\ g\ O_2 \times \frac{1\ mole\ O_2}{32.00\ g\ O_2} \times \frac{1\ mole\ CO_2}{1\ mole\ O_2} \times \frac{44.01\ g\ CO_2}{1\ mole\ CO_2} = \boxed{48.1\ g\ CO_2}$$

So the O_2 is limiting, and the reaction will yield 48.1 g CO_2

How Much of the Excess is Left

$$C + O_2 \rightarrow CO_2$$

How much of the C is used when all of the O_2 is consumed?

$$35.0\ g\ \mathrm{O_2} \times \frac{1\ mole\ \mathrm{O_2}}{32.00\ g\ \mathrm{O_2}} \times \frac{1\ mole\ \mathrm{C}}{1\ mole\ \mathrm{O_2}} \times \frac{12.01\ g\ \mathrm{C}}{1\ mole\ \mathrm{C}} = 13.1\ g\ \mathrm{C}$$

Next calculate how much C is left by subtracting what was used:

$$55.0\ g\ \mathrm{C}\ (\text{given}) - 13.1\ g\ \mathrm{C}\ (\text{used}) = 41.9\ g\ \mathrm{C\ excess}$$

So 41.9 g C is left (excess) after all of the O_2 is consumed.

Limiting & Excess Reagent

In this problem:

- 48.1 g CO_2 is produced.
- O_2 is the limiting reagent and is used up
- C is the excess reagent
- 41.9 grams of C is left as excess reagent

Percent Yield

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

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

<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

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

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

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