Stoichiometry

Objectives

- Write a unit equation for a balanced chemical equation that relates the number of moles of one substance to the number of moles of another substance.
- Perform mole-mole stoichiometry calculations.
- Perform mass-mass stoichiometry calculations.
- Perform mass-volume stoichiometry calculations.
- Perform volume-volume stoichiometry calculations.
- Explain the concept of a limiting reactant.

Objectives

- Identify the limiting reactant in a chemical reaction given the number of moles of each reactant.
- Perform mass-mass stoichiometry calculations involving a limiting reactant.
- Perform mass-volume stoichiometry calculations involving a limi9ting reactant.
- Perform volume-volume stoichiometry calculations involving a limiting reactant.
- Calculate the percent yield for a reaction, given the actual yield and the theoretical yield.

Mole – Mole Problems

- Write the balanced chemical equation for the reaction.
- Find the ratio of the number of moles of each substance.
- Use the ratio as a Unit Factor to find the number of moles of the other substance.

Sample Mole – Mole Problem

Nitrogen gas combines with oxygen gas according to the equation: $N_2 + O_2 \rightarrow NO$. How many moles of NO are produced when 2.25 moles of oxygen react with nitrogen?

Balance Equation: $N_2 + O_2 \rightarrow 2NO$

Unit Equation: 2 mol NO = 1 mol O_2

Find Moles NO: 2.25 mol O_2 X 2 mol NO/1 mol O_2 = 4.5 mol NO

Sample Mole – Mole Problem

12.5 moles of Fe_2O_3 reacts with CO to produce Fe and CO_2 according to the equation: $Fe_2O_3 + CO \rightarrow Fe + CO_2$. How many moles of CO_2 are produced?

Balance Equation: $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

Unit Equation: 3 mol CO_2 = 1 mol Fe_2O_3

Find Moles of CO_2:

12.5 mol Fe_2O_3 X 3 mol CO_2/1 mol Fe_2O_3 = 37.5 mol CO_2

Mass – Mass Problems

- Write the balanced chemical equation for the reaction.
- From the mass of the given substance, calculate the number of moles of that substance.
- Find the ratio of the number of moles of each substance from the coefficients in the balanced equation.
- Use the ratio as a unit factor to find the number of moles of the second substance.
- Calculate the mass of the second substance.

Sample Mass – Mass Problem

Carbon combines with oxygen to produce carbon monoxide according to the equation:

$$C + O_2 \rightarrow CO$$

Find the mass of CO produced from 28.0 g of carbon.

Balance Equation: $2C + O_2 \rightarrow 2CO$

Calculate moles of C:

28.0 g C X 1 mol C/12.00 g C = 2.33 mol C

Unit Equation: 2 mol CO = 2 mol C

Find moles of CO:

2.33 mol C X 2 mol CO/2 mol C = 2.33 mol CO

Calculate mass of CO:

2.33 mol CO X 28.01 g CO/1 mol CO = 65.4 g CO

Mass – Volume Problems

- Write the balanced chemical equation for the reaction.
- From the mass or volume of the first substance, calculate the number of moles of that substance.
- Find the ratio of the number of moles of each substance from the coefficients in the balanced equation.
- Use the ratio as a unit factor to find the number of moles of the other substance.
- Calculate the volume or mass of the second substance.

Sample Mass – Volume Problem

Consider the reaction in the previous problem. How many liters of CO result from the combination of 28.0 g of C and O_2?

Balance Equation: $2C + O_2 \rightarrow 2CO$

Calculate moles of C: 28 g C X 1 mol C/12.01 g C = 2.33 mol C

Unit Equation: 2 mol CO = 2 mol C

Find moles of CO:

2.33 mol C X 2 mol CO/2 mol C = 2.33 mol CO

Calculate volume of CO:

2.33 mol CO X 22.4 L CO/1 mol CO = 52.2 L CO

Volume - Volume Problems

- Write the balanced chemical equation for the reaction
- From the volume of the first substance, calculate the number of moles of that substance.
- Find the ratio of the number of moles of each substance from the coefficients in the balanced equation.
- Use the ratio as a unit factor to find the number of moles of the second substance
- Calculate the volume of the second substance.

Sample Volume - Volume Problem

Find the volume of CO produced when 12.0 L of O_2 combine with carbon.

Balance Equation: $2C + O_2 \rightarrow 2CO$

Calculate moles of O_2:

$12.0 \text{ L } O_2 \text{ X } 1 \text{ mol } O_2 / 22.4 \text{ L } O_2 = 0.536 \text{ mol } O_2$

Unit Equation: $2 \text{ mol CO} = 1 \text{ mol } O_2$

Find moles of CO:

$0.536 \text{ mol } O_2 \text{ X } 2 \text{ mol CO} / 1 \text{ mol } O_2 = 1.07 \text{ mol CO}$

Calculate volume of CO:

$1.07 \text{ mol CO X } 22.4 \text{ L CO} / 1 \text{ mol CO} = 24.0 \text{ L CO}$

Limiting Reactant Problems

- Calculate the number of moles of product using the amount of the first substance.
- Calculate the number of moles of product using the amount of the second substance.
- The amount of product will be equal to the smaller of these two results.

Sample Limiting Reactant Problem

How much iron will be produced when 98.0 g of FeO react with 56.0 g of Al?

Balance equation: $3FeO + 2Al \rightarrow 3Fe + Al_2O_3$

Find Moles of FeO:

98.0 g FeO X 1 mol FeO/65.9 g FeO = 1.49 mol FeO

Unit Equation: 3 mol Fe = 3 mol FeO

Find Moles Fe:

1.49 mol FeO X 1 mol Fe/1mol FeO = **1.49 mol Fe**

Sample Limiting Reactant Problem

How much iron will be produced when 98.0 g of FeO react with 56.0 g of Al?

Balance equation: $3FeO + 2Al \rightarrow 3Fe + Al_2O_3$

Find Moles of Al: 56.0 g Al X 1 mol Al/27.0 g Al = 2.07 mol Al

Unit Equation: 3 mol Fe = 2 mol Al

Find Moles Fe: 2.07 mol Al X 3 mol Fe/2 mol Al = **3.11 mol Fe**

More product would be produced with 56.0 g of aluminum and an unlimited supply of FeO than with 98.0 g of FeO and an unlimited supply of Al. Therefore, in this situation, FeO is the limiting reactant.

Percent Yield

- The percent yield is the actual yield divided by the theoretical yield multiplied by 100%
  - Percent yield = (actual yield/theoretical yield) X 100%

Sample Percent Yield Problem

- If 15 kg of ammonia give an actual yield of 65.3 kg of ammonium nitrate, what is the percent yield? The calculated yield of ammonium nitrate for the experiment is 70.5 kg.

Given: Actual yield = 65.3 kg
Theoretical yield = 70.5 kg
Percent yield = ?

Percent Yield = (Actual/Theoretical) X 100%
Percent Yield = (65.3 kg/70.5 kg) X 100%
Percent Yield = 92.6%