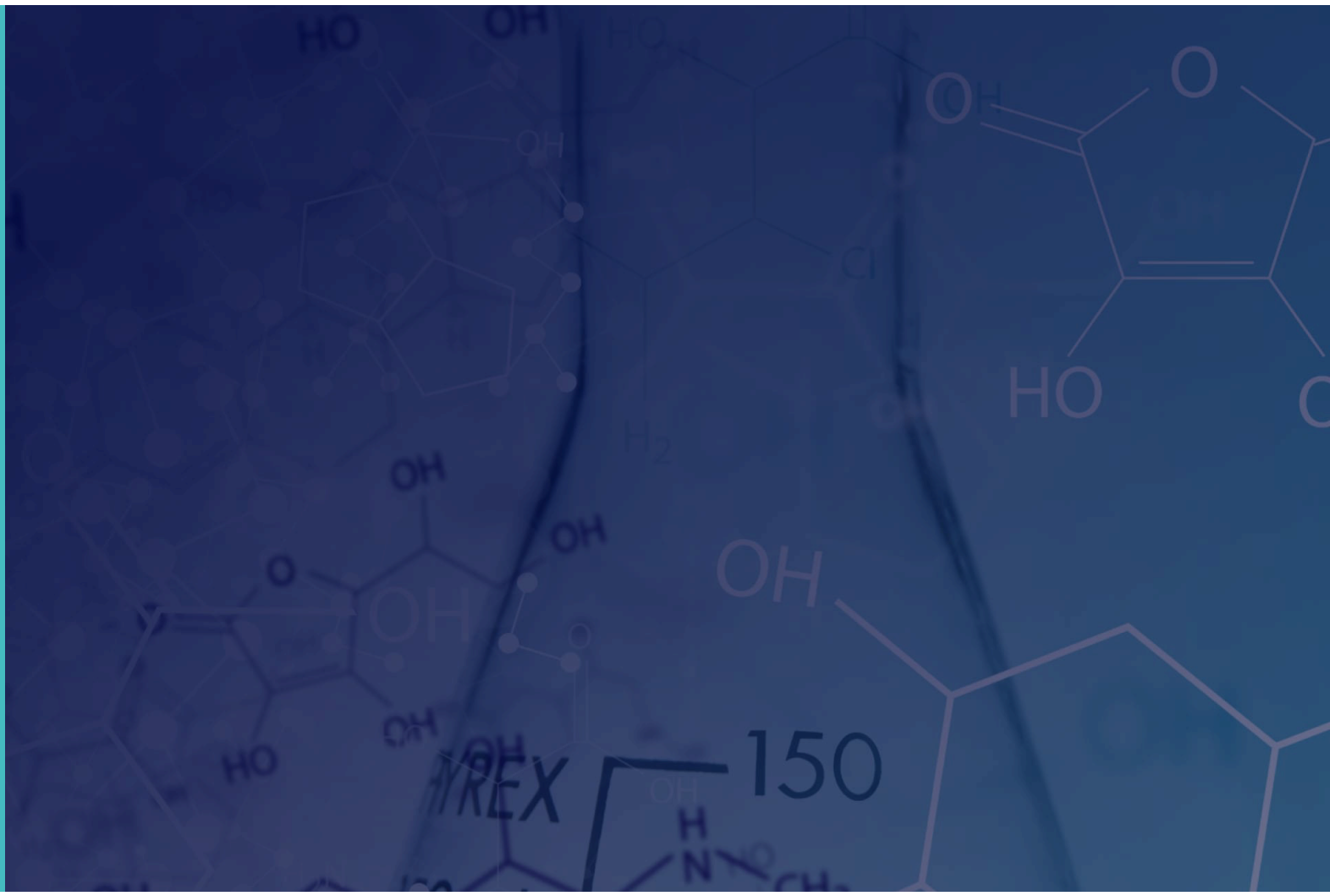


Ontario High School

Grade 11 Chemistry

Summer 2024, Chapter 6 Notes

Table of Contents

6. Stoichiometry

6.1 Stoichiometry

6.1.1

Mole Ratios

- **Stoichiometry** is the relationship between the amount of reactants used in a chemical reaction and the amount of products made.

2 slices of bread | 1 slice of cheese | 1 grilled cheese sandwich

- The **stoichiometric coefficients** tells us that if we wanted to make one grilled cheese sandwich, we need two slices of bread and one slice of cheese
- We can represent this using a mole ratio

$$\frac{2 \text{ slices of bread}}{1 \text{ slice of cheese}} \text{ or } \frac{1 \text{ slice of cheese}}{1 \text{ grilled cheese sandwich}} \text{ or } \frac{2 \text{ slices of bread}}{1 \text{ grilled cheese sandwich}}$$

- Mole ratios can then be used to convert between amounts of any two substances in a chemical reaction

6.1.2

Stoichiometry of a Reaction

- We use the **coefficients** of the **balanced reaction** along with the our equations that convert mass, volume, and concentration into moles to predict the quantities of reactants and products in a chemical reaction.
- To answer any stoichiometry problem, **focus on converting to and from moles!** Moles are the central unit!

MASS

$$n = \frac{m}{M}$$

m = mass (g)

M = molar mass (g/mol)

PRESSURE

$$n = \frac{PV}{RT}$$

P = pressure (kPa)

V = volume (L)

R = gas constant (8.314 $L \cdot kPa \cdot mol^{-1} \cdot K^{-1}$

T = temperature (K)

MOLES

n = moles (mol)

SOLUTION

$$n = cV$$

c = concentration (mol/L)

V = volume (L)

NUMBER OF ENTITIES

$$n = \frac{N}{N_A}$$

N = number of entities

N_A = Avogadro's number (6.023×10^{23} mol^{-1})

General Steps to Solving a Stoichiometry Problem:

1. Convert the values given in the problem about a reactant or product to a **number of moles**
2. Use the **stoichiometric coefficients** from the **balanced** reaction to **find the number of moles of the unknown** you are being asked for
3. Convert the number of moles of your unknown to a mass, or whatever quantity you are being asked for

6.1.3 Example: Gravimetric Stoichiometry

Example: Gravimetric Stoichiometry

Silver metal can be recovered from waste silver nitrate solutions by reaction with copper metal. What mass of silver can be obtained using 50 g of copper?

$$2AgNO_3(aq) + Cu(s) \rightarrow 2Ag(s) + Cu(NO_3)_2(aq)$$

Solution available online

2.

3.

6.1.4

How many moles of H_2 and N_2 can be formed by the decomposition of 12.7mol of ammonia, NH_3? Do not include units in your answer.

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

moles of N2:

---

moles of H2:

6.1.5

Practice: Stoichiometry

Calculate the mass of iron (III) oxide (rust), in grams, produced by the reaction of 250 g of iron with oxygen from the air. Round your answer to the nearest integer; do not include units.

Answer

6.1.6

The thermite reaction is used for welding railroad rails. The reaction is:

$$Fe_3O_3(s) + 2Al(s) \rightarrow 3Fe(s) + Al_2O_3(\mathrm{s})$$

If 25g of iron, Fe(s), are produced from a reaction how many grams of aluminum oxide are generated?

- 15g
- 23g
- 27g
- 55g
- 57g

6.2 Limiting Reagents

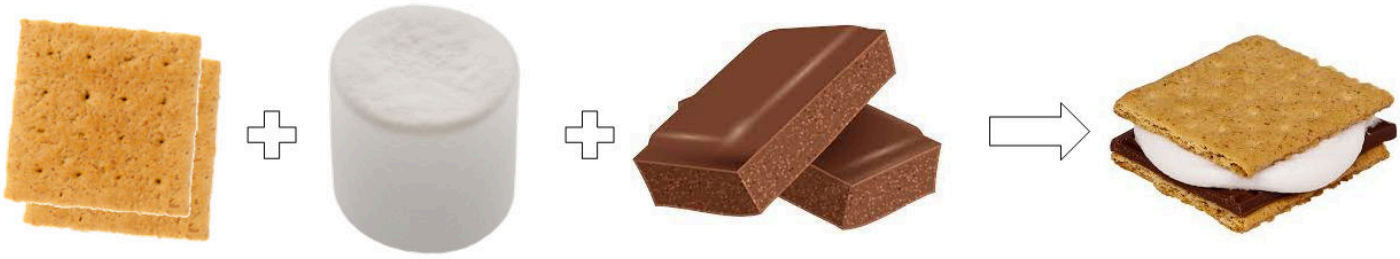
6.2.1

Limiting and Excess Reagents

- Anytime **reactant species are in limited supply** and not present in perfectly proportional amounts, a chemical reaction will have a **limiting reagent**
- The limiting reagent will be totally **consumed before any other reactant**
- The quantity of the limiting reagent available directly **determines the maximum number of product molecules** that can be formed
- **Excess reagents** are reactants that remain after the reaction is complete

How to find Limiting and Excess Reagents

- When making smores the "reaction" looks something like:



- If I had 10 graham crackers, 6 chocolate squares, and 6 marshmallows, what would be the limiting reagent?
- One way to find the limiting reagent is to use the mole ratio to figure out how much product each reagent would give you

- The questions you are asking yourself are:
  - how many s'mores can I make with 10 graham crackers?
  - how many s'mores can I make with 6 chocolate squares?
  - how many s'mores can I make with 6 marshmallows?
- Now, **to figure out the limiting reagent, look at which of reagent gives you the least amount of s'mores**

- We say that the graham crackers and marshmallow are **excess reagents.** There will be leftover graham crackers and marshmallows.
    - how many graham crackers will be used up and how many will be left over?
    - how many marshmallows will be used up and how many will be left over?

6.2.2

Example: Determine the Mass of Product in a Limiting Reagent Problem

Iron and chlorine gas react to form iron (III) trichloride. If 110 g of iron and 105 g of chlorine gas are reacted, which species is the limiting reagent? What is the maximum mass of $FeCl_3$ that can be formed?

$$2Fe(s) + 3C\ell_2(g) \rightarrow 2FeC\ell_3(s)$$

-
-
-

6.2.3

Example: Determine the Amount of Excess Reagent

The reaction between P_4 and Br_2 is very exothermic and results in PBr_5 as the only product. If 7.0 g of P_4 react with 12.0 g of Br_2 how many grams of the excess reagent will remain?

$$P_4(s) + 10Br_2(\ell) \rightarrow 4PBr_5(s)$$

6.2.4

Practice: Finding Limiting Reagents

Hydrogen gas reacts with oxygen gas to produce water. When 0.20g H_2 are mixed with 0.50g O_2, which gas is the limiting reagent?

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$$

- hydrogen gas
- oxygen gas
- water
- we do not have enough information to determine the limiting reagent

6.2.5

What is the maximum mass of $Ca(CN)_2$ that can be obtained from 1.56 g of HCN and 2.58 g of $Ca(OH)_2$? The balanced chemical equation is shown below.

$$\underset{27.03g/mol}{2HCN(aq)} + \underset{74.10g/mol}{Ca(OH)_2(aq)} \rightarrow \underset{92.12g/mol}{Ca(CN)_2(aq)} + \underset{18.02g/mol}{2H_2O(\ell)}$$

- 5.31g
- 2.20g
- 2.66g
- 1.37g
- 3.21g

6.3 Percent Yield

6.3.1

Percent Yield

- Often, during chemical reactions in a laboratory, we cannot recover 100% of the product expected. This could be because:
  - Reactants or products are lost when they are being transferred
  - You may have undesirable side reactions
  - Your reaction may be incomplete
- The amount of product that we expect from a stoichiometric calculation is known as the **theoretical yield**
- We refer to the product amount that is weighed and recovered as the **actual yield**
- We get the **percent yield** of a reaction by comparing the actual yield to the theoretical yield of a reaction

$$\boxed{\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%}$$

Example: Calculating Percent Yield

When 49.00g of a hydrocarbon fuel with formula $C_7H_{10}O_2$ is reacted with excess oxygen, a total of 21.56g of water is collected. What was the percent yield of the reaction?

$$2C_7H_{10}O_2 + 17O_2 \rightarrow 10H_2O + 14CO_2$$

6.3.3

The balanced equation for the complete combustion of butane is as follows:

$$4C_4H_10 + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

In an experiment, 12.37 g of carbon dioxide was produced when 14.25 g was predicted. What is the percentage yield? Round your answer to the nearest integer; do not include the % symbol.

Answer

6.3.4

Consider the following reaction:

$$PC\ell_3 + C\ell_2 \rightarrow PC\ell_5$$

If the yield of the reaction is 76.5 %, what is the mass of PCl_5 , in grams, obtained from the reaction of 27.0 g of PCl_3 with excess Cl_2? Give your answer to one decimal place; do not include units in your answer.

Answer

6.3.5

In the balanced reaction below, a student reacts 1.25g of copper with 5.0mL of 12.0mol/L HCl.

$$Cu(s) + 2HC\ell(aq) \rightarrow CuC\ell_2(aq) + H_2(g)$$

Part 1

Calculate the theoretical yield of hydrogen gas produced in grams. Give your answer to four decimal points; do not include units.

Answer

In the balanced reaction below, a student reacts 1.25g of copper with 5.0mL of 12.0mol/L HCl.

$$Cu(s) + 2HC\ell(aq) \rightarrow CuC\ell_2(aq) + H_2(g)$$

Part 2

Determine the percent yield of this reaction if a student collected 0.0321g of hydrogen gas. Round your answer to the nearest whole integer; do not include symbols.

Answer
