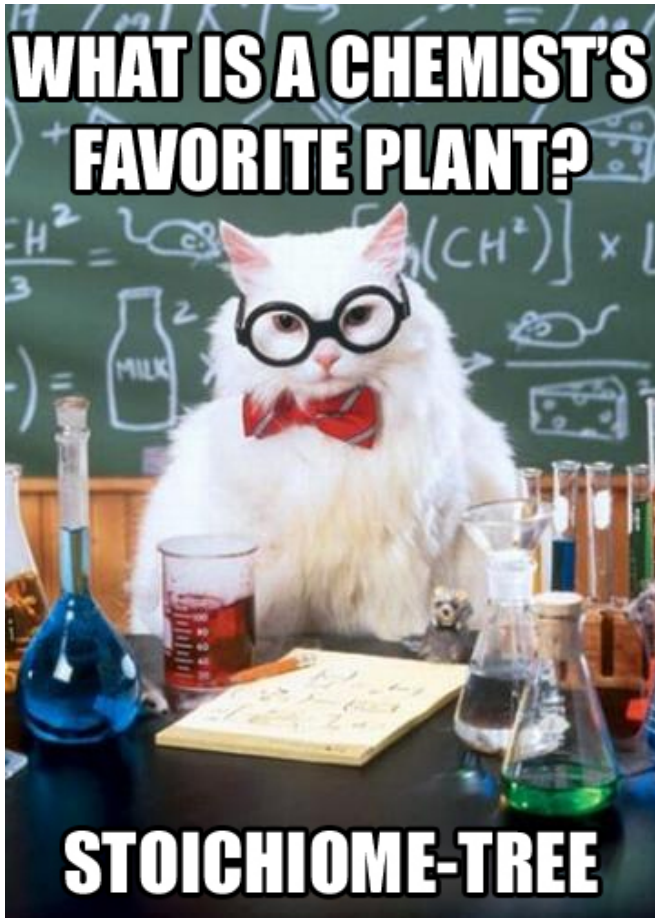
Stoichiometry



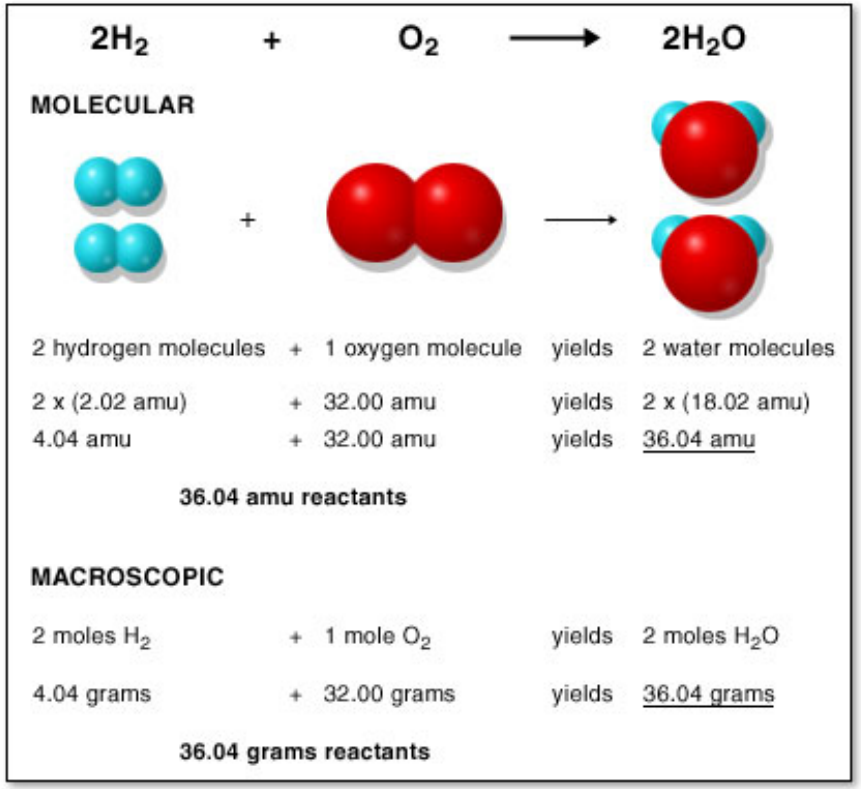
Outcomes:

- Interpret a balanced chemical equation in terms of moles, mass and volume of gases.
- Solve stoichiometric problems involving: moles, mass, volume, and heat of reaction.

Stoichiometry Introduction

Stoichiometry

- Is the study of the **QUANTITATIVE RELATIONS** between the **AMOUNTS** of **REACTANTS** and **PRODUCTS**.
- Just like in cooking, the **AMOUNTS** and **PROPORTIONS** of ingredients determine the **AMOUNT** of food you can



http://www.mhhe.com/physsci/chemistry/chang7/esp/folder_structure/cr/m2/s1/

Stoichiometry Introduction

Mole Ratios

- Is the **RATIO** of the number of **MOLES** of **REACTANTS** and **PRODUCTS** in a **BALANCED** chemical **REACTION**.
- To get mole ratios, you must ensure that the equation is **BALANCED**.

Examples:

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

   1 : 3 : 2

2. $2KClO_3 \rightarrow 2KCl + 3O_2$

   2 : 2 : 3

3. $Zn + 2HCl \rightarrow ZnCl_2 + H_2$

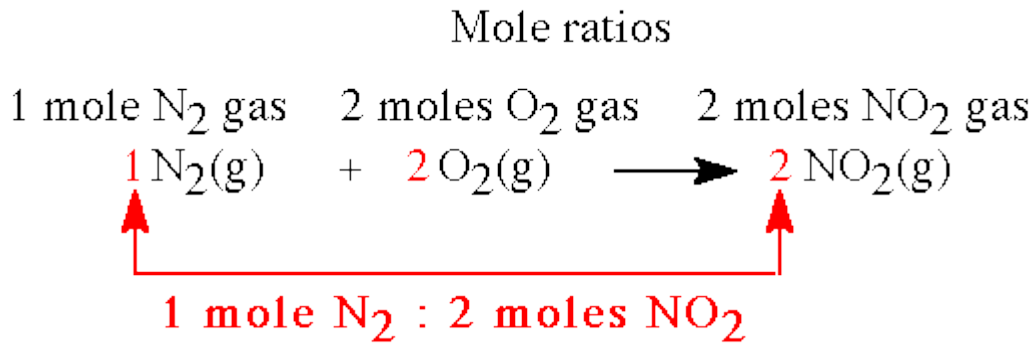
   1 : 2 : 1 : 1

The mole ratio shows us the **PROPORTIONS** of reactants that produce a certain amount of **PRODUCTS**.

Stoichiometry Introduction

Mole-Mole Stoichiometry:

- Allows ~~is~~ us to find the number of **MOLES** of **PRODUCT** that will be formed when we are **GIVEN** the **NUMBER** of **MOLES** of a **REACTANT** (and vice-versa)
- Will also allow us to find the number of moles of one **REACTANT** **NEEDED** when we are **GIVEN** the **MOLES** of the **OTHER** **REACTANT**.
- In other words, if we know the number of **MOLES** of just ***one*** of the **REACTANTS** or **PRODUCTS**, we can find the number of **MOLES** of **ALL** other **SPECIES** in the reaction.



http://www.800mainstreet.com/6/0006-005a-equation_mol-rat.html

Mole–Mole Stoichiometry

Example:

1. How many moles of hydrogen gas are needed to completely react with 2.00 moles of nitrogen gas to produce ammonia?

Step 1: *write the balanced equation.*

$$3H_2 + 1N_2 \longrightarrow 2NH_3$$

Step 2: *Set up a molar ratio.*

- *we see that 1mol of N_2 reacts with 3mol of H_2.*

$$\frac{3\text{mol } H_2}{1\text{mol } N_2} \quad \text{OR} \quad \frac{1\text{mol } N_2}{3\text{mol } H_2}$$

Step 3: *Set up the equation:*

- *To solve for the moles H_2 needed, start with the given 2.00mol N_2, Then use the molar ratio that allows the units to cancel.*

$$2.00\text{mol } N_2 \times \frac{3\text{ mol } H_2}{1\text{ mol } N_2} = 6\text{ mol } H_2$$

Mole–Mole Stoichiometry

Example:

2. How many moles of Ammonia are produced when 0.6 mol Nitrogen gas reacts with hydrogen gas.

Step 1: *write the balanced equation.*

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

Step 2: *Set up a molar ratio.*

$$\frac{1\ mol\ N_2}{2\ mol\ NH_3} \quad or \quad \frac{2\ mol\ NH_3}{1\ mol\ N_2}$$

Step 3: *Set up the equation:*

$$0.6\ \cancel{mol\ N_2} \times \frac{2\ mol\ NH_3}{1\ \cancel{mol\ N_2}} = 1.2\ mol\ NH_3$$

Mole–Mole Stoichiometry

Zn^{2+} Cl^-

Try this one…

How many moles of Hydrogen gas are produced from the reaction of 3.00 moles of zinc with HCl?

$$1\,Zn + 2HCl \rightarrow 1\,H_2 + ZnCl_2$$

$$3\,\text{mol}\,Zn \times \frac{1\,\text{mol}\,H_2}{1\,\text{mol}\,Zn} = 3\,\text{mol}\,H_2$$

Mole–Mass Stoichiometry

Moles to Mass Problems

Same idea as mole to mole problems, but we give you moles of one substance, and you need to convert your answer to mass…

Steps:

1. Write the **BALANCED EQUATION**
2. Write down the **MOLES** of the **GIVEN SUBSTANCE**.
3. Multiply by the **MOLE RATIO** that will **CANCEL** the given units and leave you with **MOLES** of what you are **LOOKING FOR**.
4. Convert the moles to **GRAMS** (use **MOLAR MASS**)

Mole–Mass Stoichiometry

Examples:

1. What mass of water is produced when 4 moles of hydrogen gas reacts with excess oxygen?

Balanced Equation:

Find moles of water produced:

Convert to grams of water produced:

Mole–Mass Stoichiometry

Examples:

2. What mass of aluminum hydroxide is produced when 1.5 moles of sodium hydroxide reacts with excess aluminum chloride?

Balanced Equation:

Find moles of water produced:

Convert to grams of water produced:

Mole–Mass Stoichiometry

Try these ones...

1. Find the mass of carbon dioxide produced when 2.5 moles of propane (C_3H_8) react with excess oxygen.

Mole–Mass Stoichiometry

Try these ones...

2. Find the mass of calcium chloride produced when 0.5 moles of magnesium chloride react with excess calcium hydroxide.

Mass–Mass Stoichiometry

Mass-Mass Relationships

- Same idea as ***mole-mole*** stoichiometry.
- Given **MASS** of **ONE SPECIES** in a reaction, find **MASS** of **ANOTHER SPECIES** in the reaction.

Steps:

1. Write the **BALANCED EQUATION**.
2. **CONVERT** the given **MASS** to **MOLES**
3. Set up a **MOLAR RATIO** and **SOLVE** for the **REQUIRED MOLES**.
4. **CONVERT** the calculated **MOLES** to **GRAMS**.

Mass–Mass Stoichiometry

Example:

Find the mass of ammonia produced when 3.6g of hydrogen gas reacts with nitrogen gas.

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

3.6g ? g

$$3.6\,g\,H_2 \times \frac{1\ mol}{2.02\ g} = 1.78\,mol\,H_2 \times \frac{2\ mol\ NH_3}{3\ mol\ H_2} = 1.19\,mol\ NH_3 \times \frac{17.03\ g}{1\ mol} = \boxed{20.27\,g\ NH_3}$$

Mass–Mass Stoichiometry

Try this one…

Reactants → Products

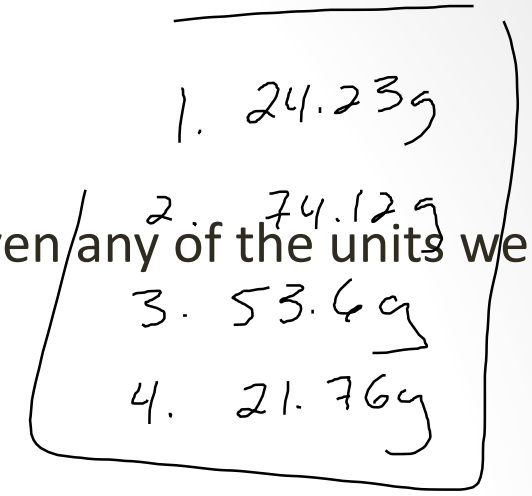
How many grams of $Cu(OH)_2$ can be produced from the reaction of 12.7g of $Cu(NO_3)_2$ reacting with excess NaOH?

$$Cu(NO_3)_2 + 2NaOH \rightarrow Cu(OH)_2 + 2NaNO_3$$

$$12.7\,g\,Cu(NO_3)_2 \times \frac{1\,mol}{187.5\,g} = 0.068\,mol\,Cu(NO_3)_2 \times \frac{1\,mol\,Cu(OH)_2}{1\,mol\,Cu(NO_3)_2} = 0.068\,mol\,Cu(OH)_2 \times \frac{97.52\,g}{1\,mol}$$

$$= 6.63\,g\,Cu(OH)_2$$

Solving any Stoichiometry Problem



Stoichiometry doesn't have to just deal with masses. You could be given any of the units we have studied, and be asked to state your answer in any of these units:

MOLES **VOLUME** **MASS** **# OF PARTICLES**

To solve any stoichiometry problem, follow these steps:

1. Write the **BALANCED** reaction.
2. **CONVERT** the **GIVEN** units to **MOLES** (if not already in moles)
3. Set up a **MOLAR RATIO**, and **SOLVE** for the moles of the **REQUIRED** species **ALGEBRAICALLY**.
4. **CONVERT** your answer to the **UNIT ASKED FOR** in the question (moles, grams, liters, particles)

STOICH

NOTE:

- Ensure all **MASSES** are in **GRAMS** (1kg = 1000g)
- Ensure all **VOLUMES** are in **LITRES** (1L = 1000mL)

Solving any Stoichiometry Problem

Examples:

1. Find the volume (@ STP) of ammonia produced when 3.0L of nitrogen gas reacts with hydrogen gas.

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

$$3.0\,L\ N_2 \times \frac{1\ mol}{22.4\ L} = 0.13\ mol\ N_2 \times \frac{2\ mol\ NH_3}{1\ mol\ N_2} = 0.26\ mol\ NH_3 \times \frac{22.4\ L}{1\ mol} = 6.0\,L\ NH_3$$

Solving any Stoichiometry Problem

Examples:

2. How many litres of carbon dioxide are produced when 55.0g of methane (CH_4) is burned at STP?

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

$$55\,g\,CH_4 \times \frac{1\,mol}{16.04\,g} = 3.43\,mol\,CH_4 \times \frac{1\,mol\,CO_2}{1\,mol\,CH_4} = 3.43\,mol\,CO_2 \times \frac{22.4\,L}{1\,mol} = 76.8\,L\,CO_2$$

Solving any Stoichiometry Problem

Examples:

3. How many liters of carbon dioxide are produced when 55.0g of methane (CH_4) is burned at STP?

Solving any Stoichiometry Problem

Examples:

3. How many liters of carbon dioxide are produced when 55.0g of methane (CH_4) is burned at STP?

Solving any Stoichiometry Problem

Try these ones…

1. Find the mass of ammonia produced when 3.0L of nitrogen gas reacts with excess hydrogen gas at S.T.P.

4.56g

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

$$3.0\,L\,N_2 \times \frac{1\,mol}{22.4\,L} = 0.13\,mol\,N_2 \times \frac{2\,mol\,NH_3}{1\,mol\,N_2} = 0.26\,mol\,NH_3 \times \frac{17.03\,g}{1\,mol} = \boxed{4.56\,g}$$

Solving any Stoichiometry Problem

Try these ones…

2. Given the reaction below, what mass of glucose ($C_6H_{12}O_6$) is needed to make 4.5L CO_2 gas at STP? ***(note: the reaction is not balanced)***

18.08g

$$C_6H_{12}O_6 \rightarrow 2\,C_2H_5OH + 2\,CO_2$$

$$4.5\,L\ CO_2 \times \frac{1\,mol}{22.4\,L} = 0.2\,mol\ CO_2 \times \frac{1\,mol\ C_6H_{12}O_6}{2\,mol\ CO_2} = 0.1\,mol\ C_6H_{12}O_6 \times \frac{180.12\,g}{1\,mol} = \boxed{18.01\,g\ C_6H_{12}O_6}$$