Stoichiometry

A Quantitative Analysis

Chemical Quantities and Reaction Types

Learning Target: **I can identify the six types of chemical reactions by predicting the products of each type of reaction.**

March 8, 2021

Pre-Test Here:

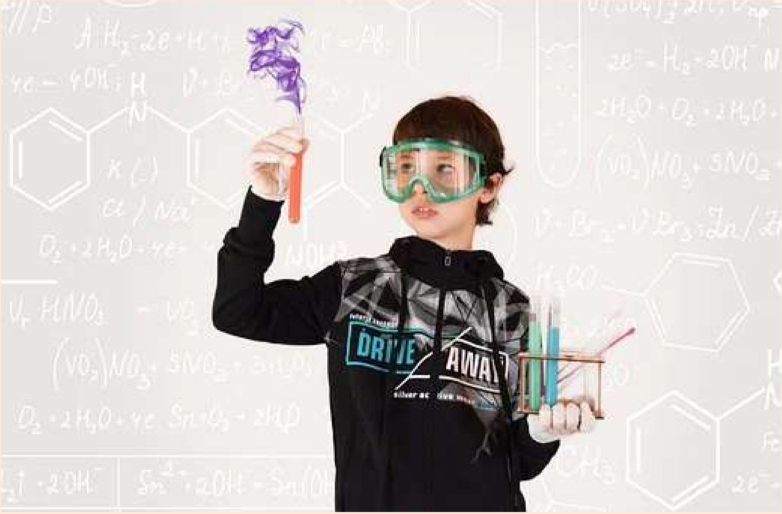
Link to Pre-Test

Files for Stoichiometry Unit

- Stoichiometry Problem Set
- Stoichiometry Guided Notes

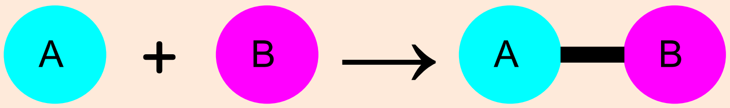
Reaction Types

- Combination/Synthesis
- Decomposition
- Single replacement
- Double replacement
- Combustion
- Neutralization



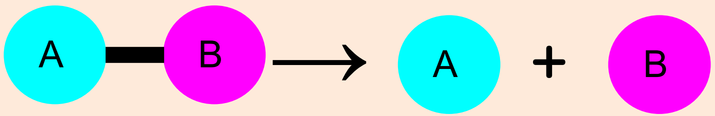
Combination/Synthesis

❖ Two or more molecules combine to a form a main product.

Mechanism	Example
$A + B \rightarrow AB$  	$NH_3(g) + HCl(g) \rightarrow NH_4Cl(g)$ $2Na(s) + Cl_2(g) \rightarrow$ (s)

Decomposition

- A single molecule breaks down to form two or more products.

Mechanism	Examples
$AB \rightarrow A + B$ 	$CaCO_3(s) \rightarrow CaO(s) + CO_2(s)$ $H_2SO_3(aq) \rightarrow H_2O(l) + \underline{\quad}(g)$ $2HgO(s) \rightarrow 2\underline{\quad}(l) + \underline{\quad}_2(g)$ $2H_2O(l) \rightarrow 2\underline{\quad}_2(g) + \underline{\quad}_2(g)$

Single Replacement

❖ An atom displaces another atom or constituent on another molecule.

Mechanism	Example
A + BX → B + AX	$2AgNO_3(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + 2Ag(s)$ $2NaBr(aq) + Cl_2(g) \rightarrow 2Na\_\_(s) + \_\_{}_2(l)$

Double Replacement

- Two molecules exchange either cations or anions

Mechanism	Example
$AY + BX \rightarrow AX + BY$	$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow BaSO_4(s) + 2NaCl(aq)$ $Pb(NO_3)_2(aq) + 2KI(aq) \rightarrow 2\quad(aq) + PbI_2(s)$

Combustion

- The process of burning or igniting something
  - The general form is: Fuel + O_2 → Water + Carbon/Carbon oxides
  - Oxygen-rich environments are necessary for better combustion

- Complete combustion: CO_2 is produced (better for environment!)

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$$

- Incomplete combustion: CO and C (soot) are produced

$$2C_2H_6 + 5O_2 \rightarrow 4CO + 6H_2O$$

$$2C_2H_6 + 3O_2 \rightarrow 4C + 6H_2O$$

Combustion

Write the balanced chemical equations for the complete combustion of each of the following hydrocarbons:

C_2H_2, C_3H_8, C_7H_{16}, CH_3OH

$\_\_ C_2H_2 + \_\_ O_2 \rightarrow \_\_ CO_2 + \_\_ H_2O$

$\_\_ C_3H_8 + \_\_ O_2 \rightarrow \_\_ CO_2 + \_\_ H_2O$

$\_\_ C_7H_{16} + \_\_ O_2 \rightarrow \_\_ CO_2 + \_\_ H_2O$

$\_\_ CH_3OH + \_\_ O_2 \rightarrow \_\_ CO_2 + \_\_ H_2O$

CAUTION:
TNT

(ANSWERS
HERE)

Neutralization

- Acid + Base → Salt + Water
  - Salts are ALWAYS ionic compounds

$HBr(aq) + KOH(aq) \rightarrow KBr(s) + H_2O(l)$

(acid) (base)

(salt) (water)

$HCl(aq) + NaOH(aq) \rightarrow$ ____ $(s) + H_2O(l)$

(acid) (base)

(salt) (water)

$HNO_3(aq) + KOH(aq) \rightarrow$ ____ $(s) + H_2O(l)$

(acid) (base) (salt) (water)

Reactions Data Table

Reaction Type	Chemical Equation	Observations (at least three per reaction)

Chemical Quantities and Reaction Types

Learning Target: **I can describe the law of conservation of mass by providing a summary of the law of conservation of mass and provide a real-world example.**

March 9, 2021

Let's Practice Writing "Chemical" Equations

Chemical equations are the "recipes" for chemical reactions.

You have 5 minutes to post a "simple" recipe for YOUR favorite food on this jamboard.

Here's how to make my favorite ice cream dish:

200g whipped cream + 450g ice cream + 250g chocolate shell drizzle + 200 g brownies + 400g chocolate chip cookie dough → 1 Pizookie

Let's Practice Writing "Chemical" Equations

Did your recipe include **counted** "units" (i.e., 5 strawberries, 40 chocolate chips),

Or did you give your recipe in terms of the **mass** of the ingredients?

In chemistry, we may need to calculate quantities from a **balanced chemical equation** using both the amount of something (3 mol H_2O) and/or the mass of something (54.06 g H_2O).

Sometimes, we might even be given the amount of particles!

Balancing Chemical Equations

Follow this link to balance the following equations:

Make ammonia:

$$\square\, N_2 + \square\, H_2 \rightarrow \square\, NH_3$$

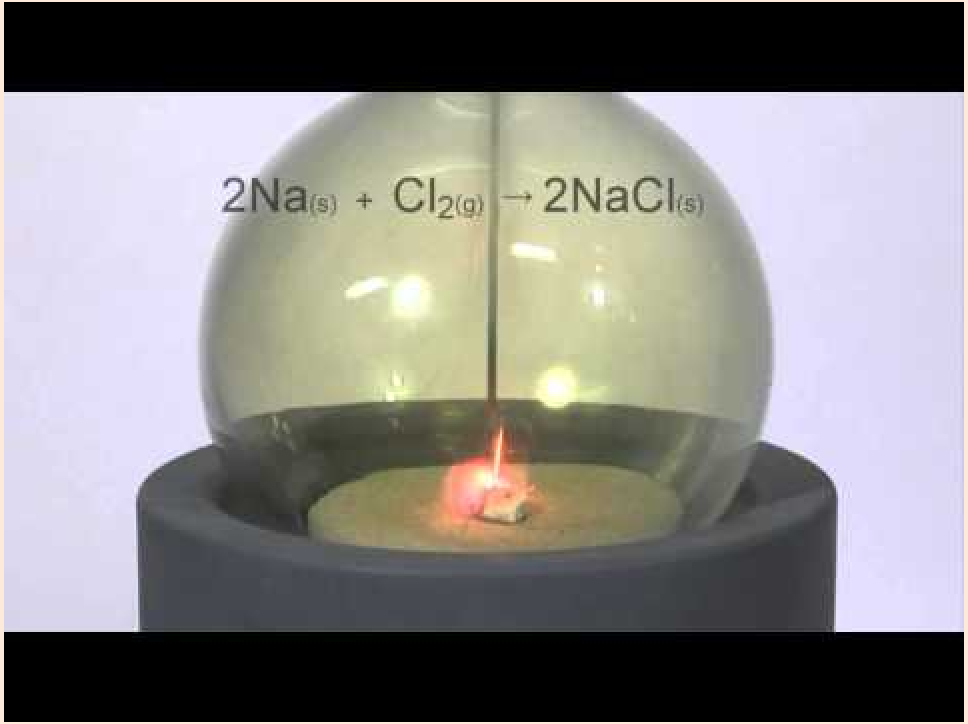
Seperate water:

$$\square\, H_2O \rightarrow \square\, H_2 + \square\, O_2$$

Combust methane:

$$\square\, CH_4 + \square\, O_2 \rightarrow H_2O + \square\, CO_2$$

How to Make NaCl in the lab!

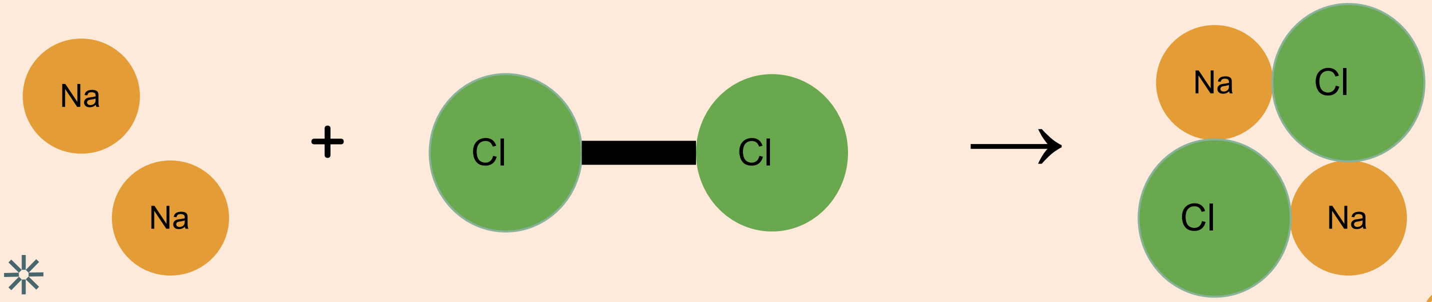


Stoichiometry

Stoichiometry is the comparison of chemical quantities in a balanced chemical reaction.

Consider the following reaction: $2Na(s) + Cl_2(g) \rightarrow 2\ NaCl\ (s)$

This chemical equation can be stated as: ____ sodium atoms react with ____ chlorine molecule to form/yield ____ formula units of sodium chloride.



Stoichiometry

Consider the following reaction: $2Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$

- How many sodium **atoms** AND chlorine **molecules** are needed to produce two molecules of NaCl?

  ___ sodium atoms and ___ chlorine molecules are required to produce ___ molecules of NaCl.

- How many **moles** of sodium AND **moles** of chlorine are needed to produce two **moles** of NaCl?

  ___ moles of sodium and ___ mole of chlorine are required to produce ___ moles of NaCl of NaCl.

Stoichiometry

EX: How many grams of sodium AND grams of chlorine are needed to produce two moles of NaCl?

$$2Na(s) + Cl_2(g) \rightarrow 2\ NaCl(s)$$

Molar mass of Na: 22.99 g/mol

Molar mass of Cl_2: 70.90 g/mol

2 mol NaCl	2 mol Na	22.99 g Na
	2 mol NaCl	1 mol Na

= ___ g Na

2 mol NaCl	1 mol Cl_2	70.90 g Cl
	2 mol NaCl	1 mol Cl_2

= ___ g Cl

Stoichiometry

2 mol NaCl	2 mol Na	22.99 g Na
	2 mol NaCl	1 mol Na

A mole to mole ratio is the ratio between the moles of any two quantities in a balanced chemical equation.

This conversion factor is called a

This conversion factor is called

We can find an element's atomic mass from the periodic table. To find the molar mass of a molecule, we have to add the atomic mass of all atoms in that molecule.

2 mol NaCl	1 mol Cl_2	70.90 g Cl
	2 mol NaCl	1 mol Cl_2

Molar Mass

For each compound, calculate the molar mass from the atomic mass of each of its constituent elements

A. Sulfuric acid (H_2SO_4): the main component of battery acid

H:	2	x	1.01 g/mol	=	/mol
S:	1	x	32.06 g/mol	=	6 g/mol
O:	4	x	16.00 g/mol	=	64.00 g/mol

32.06 g/mol is the molar mass of S

98.06 g/mol is the molar mass of H_2SO_4

Molar mass: 2.02 g/mol + 32.06 g/mol + 64.00 g/mol = **98.06 g / mol**

A. Calcium carbonate ($CaCO_3$): makes up sea shells, egg shells, and pearls

Ca:	1	x	40.08 g/mol	=	40.08 g/mol
C:	1	x	12.01 g/mol	=	12.01 g/mol
O:	3	x	16.00 g/mol	=	48.00 g/mol

Molar mass: 40.08 g/mol + 12.01 g/mol + 48.00 g/mol = **g / mol**

Mole-to-Mole Ratio

Identify the mole-to-mole ratio for each balanced chemical equation:

A. $2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$

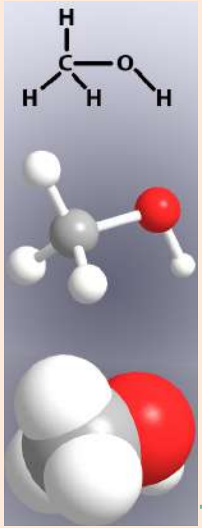
What is the mole-to-mole ratio between oxygen and dinitrogen pentoxide?

$$\frac{\_\_\_ \text{ mol } O_2}{\_\_\_ \text{ mol } N_2O_5}$$

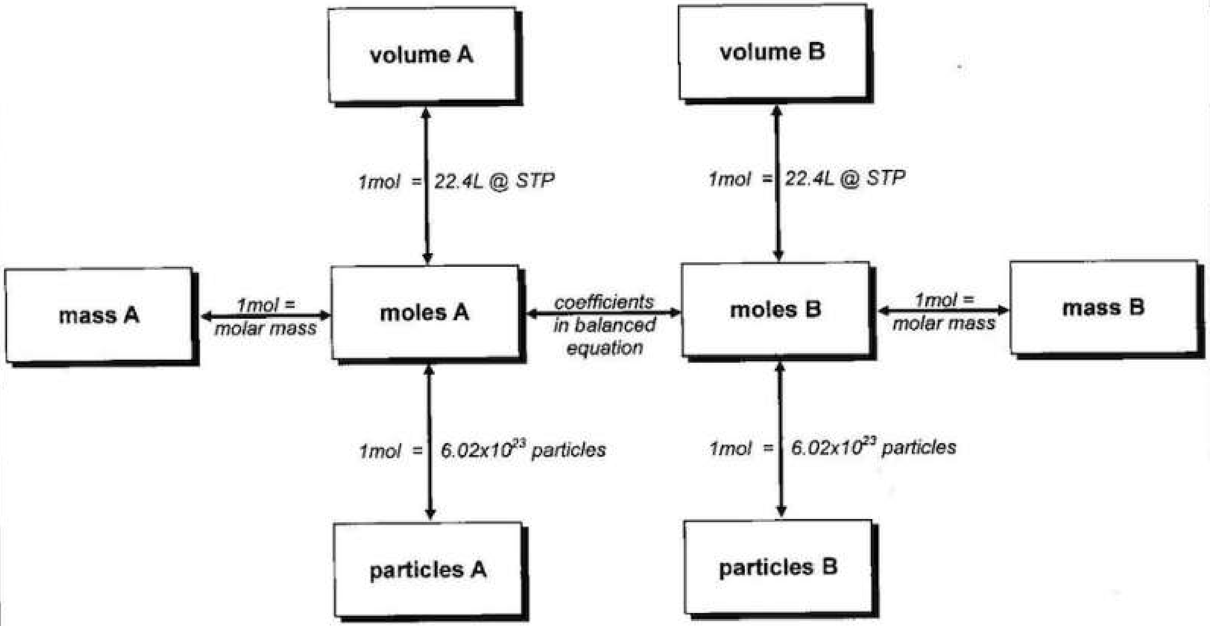
B. $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$

What is the mole-to-mole ratio between hydrogen and methanol?

$$\frac{\_\_\_ \text{ mol } H_2}{\_\_\_ \text{ mol } CH_3OH}$$



Flowchart for Mole Conversions



Law of Conservation of Mass

Law of Conservation of Mass

Mass cannot be created or destroyed in any chemical reaction

The sum of the masses of the reactants = the sum of the masses of the products

Law of Conservation of Mass

Consider the following balanced chemical equation: $NaCl(aq)$ + $AgNO_3(aq)$ → $AgCl(s)$ + $NaNO_3(aq)$

If we react 175.32 g NaCl and 509.61 g $AgNO_3$, and produce 429.96 g AgCl, how many grams of $NaNO_3$ are also produced?

Reactants	Products
175.32 g NaCl + 509.61 g $AgNO_3$ 684.93 g	429.96 g AgCl + x g $NaNO_3$ 429.6 g + x g
684.93 g = 429.60 g + x g - 429.60 g -429.60 g	
x = ____ $NaNO_3$	

Limiting Reactants and Reaction Yield

Learning Target: **I can describe the law of conservation of mass by providing a summary of the law of conservation of mass and provide a real-world example.**

March 11, 2021

Limiting Reactants

Let's imagine the equation for building a bike is as follows:

1 bike frame + **2 wheels** → **1 bike**

Limiting Reactants

Consider the “reaction”: 1 bike frame + 2 wheels → 1 bike

How many bikes can I make with...

- ❖ 1 bike frame and 2 wheels?

  Bike(s)

- ❖ 2 bike frames and 4 wheels?

  Bike(s)

- ❖ 3 bike frames and 5 wheels?

  Bike(s)

- ❖ 5 bike frames and 17 wheels?

  Bike(s)

Limiting Reactants

- The balanced chemical equation gives us the “recipe” for the reaction
  - We can be limited by the **number** of reactants just like how we can be limited by the **mass** of reactants.
  - The limiting reactant is the reactant that is **completely** consumed during the reaction.
    - Also called the limiting reagent
  - To calculate the limiting reactant, calculate the amount of product produced with each reactant, assuming the other reactant to be in excess.

Limiting Reactants

Consider the following balanced chemical equation:

$Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(l) + Al_2O_3(s)$ + heat

Calculate the amount of Fe(l) produced in grams from 35.2 g Fe_2O_3 and 75.9 g Al.

35.2 g Fe_2O_3	1 mol Fe_2O_3	2 mol Fe	55.845 g Fe	= ___ g Fe
	159.69 g Fe_2O_3	1 mol Fe_2O_3	1 mol Fe	

75.9 g Al	1 mol Al	2 mol Fe	55.845 g Fe	= ___ g Fe
	26.98 g Al	2 mol Al	1 mol Fe	

Limiting Reactants

Consider the following balanced chemical equation:

$Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(l) + Al_2O_3(s)$ + heat

Since ___ produced more product (Fe), ___ is the limiting reactant.

Question: How much ___ is left over?

We know that ___ reacted completely, so there is no more ___ available.

To find the amount of ___ left over, we subtract the initial amount by the amount that reacted.

___ g - ___ g = ___ g

Stoichiometry Practice

Consider the following balanced chemical equation:

$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$

EX: How many grams of Fe_2O_3 can be produced from 16.4g Fe and 75 g O_2?

We do not know for certain if this reaction will use **ALL** 16.4g Fe **AND** 75 g O_2

We first must find out which reactant (Fe or O_2) is consumed first, or is .

Stoichiometry Practice

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

16.4 g Fe	1 mol Fe	2 mol Fe_2O_3	159.69 g Fe_2O_3	= ____ g Fe
	55.845 g Fe	4 mol Fe	1 mol Fe_2O_3	

75.0 g O_2	1 mol O_2	2 mol Fe_2O_3	159.69 g Fe	= ____ g O_2
	32.0 g O_2	3 mol O_2	1 mol Fe_2O_3	

____ is the limiting reactant

Stoichiometry Practice

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

Claim

____ is the limiting reactant.

Evidence

The mass of iron (III) oxide produced from the mass of iron was ____ , whereas the mass of iron (III) oxide produced from the mass of oxygen gas was ____.

Reasoning

To find the limiting reactant, the amount of ____ produced in the reaction should be calculated using the masses of all reactants in separate calculations.

The limiting reactant is whichever reactant is ____ entirely during the reaction.

Limiting Reactants and Reaction Yield

Learning Target: **I can determine the limiting reactant by calculating the mass of a product produced from each reactant.**

Learning Target: **I can calculate percent yield by using the actual yield and the experimental yield.**

March 12, 2021

Reaction Yields

- **Actual yield:** The amount of substance *actually* produced from a reaction.
  - Product can be lost due to experimental error during collection or purification of a sample
- **Theoretical yield:** The maximum amount of product that can be created based on the amount of limiting reactant.
  - **The amount of product calculated when finding a limiting reactant is the theoretical yield.**
- **Percent yield:** The ratio between the actual yield and theoretical yield
  - Most of the time ≤100%
  - A reaction may have over 100% due to experimental error
  - **Percent yield = (actual yield / theoretical yield) x 100**

Link to Quizizz Here

Quizizz

Stoichiometry Practice-Salty Water

For web activity:

1. **Read** the excerpt “Desalination of Salty Water”
2. **Write** a summary of the reading using at least 3-5 sentences
3. **List** 3 key words/phrases that help to explain the process of removing salt from water.

Submit on Canvas using Google Docs.

Desalination of Salty Water

Learning Targets:

- ❖ I can create a project for the desalination of water by following an ISTE Student Standard using digital literacy skills.
- ❖ I can explain how water from the ocean is used by including a written summary with my project.
- ❖ I can demonstrate digital literacy by presenting my research from credible sources.

March 15, 2021

Stoichiometry Practice-Hydrates

Stoichiometry Puzzles Using Hydrates Pre-Lab:

1. **Read** the article "Hydrates"
2. **Define** hydrates in problem set.
3. **Watch** the video from the *Video Tutor*
4. **Copy** the question notes in the video
5. **Calculate** the question in the problem set.

Hydrates

Learning Targets:

- I can determine stoichiometric ratios between the water of hydration and anhydrous compounds by reading and writing their chemical formulas.
- I can use stoichiometry to determine the ratio of moles of water moles of salt in a hydrate by completing part one of the lab procedure on Pivot Interactives.
- I can determine the molar mass of a hydrate based on the number of moles of water by completing part two of the lab lab procedure on Pivot Interactives.

March 16, 2021

Review

Learning Targets:

- I can evaluate my readiness for the test by completing a KUD chart.
- I can use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction by completing the problem set.

March 18, 2021

Density as a Conversion Factor

- Density can be used as a conversion factor when you are given either the mass or the volume of a substance.
  - Density = mass / volume

EX: Density of water = 1 g / 1 mL

"One gram of water occupies one milliliter"

"One milliliter has a mass of one gram"

$$\frac{1\ g\ H_2O}{1\ mL\ H_2O} \quad \textbf{OR} \quad \frac{1\ mL\ H_2O}{1\ g\ H_2O}$$

Density as a Conversion Factor

EX: Ethanol (CH_3CH_2OH) has a density of 0.789 g/mL. Calculate the mass (in g) of 250 mL ethanol.

250 mL ethanol	0.789 g ethanol
	1 mL ethanol

= g ethanol

EX: The density of glycerol ($C_3H_8O_3$) is 1.26 g/mL. Calculate the volume (in mL) of 27.6 g glycerol.

27.6 g glycerol	1 mL
	1.26 glycerol

= mL glycerol

Conversion Factors Bank

<u>Avogadro's number</u>: 1 mol = 6.02 x 10^{23} particles

$$\frac{1 \text{ mol particles}}{6.02 \times 10^{23} \text{ particles}} \quad \text{OR} \quad \frac{6.02 \times 10^{23} \text{ particles}}{1 \text{ mol particles}}$$

<u>Molar mass</u>: 1 mol substance / grams substance (g/mol)

Atomic mass of He: 4.00 g / mol

$$\frac{1 \text{ mol He}}{4.00 \text{ g He}} \quad \text{OR} \quad \frac{4.00 \text{ g He}}{1 \text{ mol He}}$$

Conversion Factors Bank

<u>Density</u>: amount of mass in a given volume

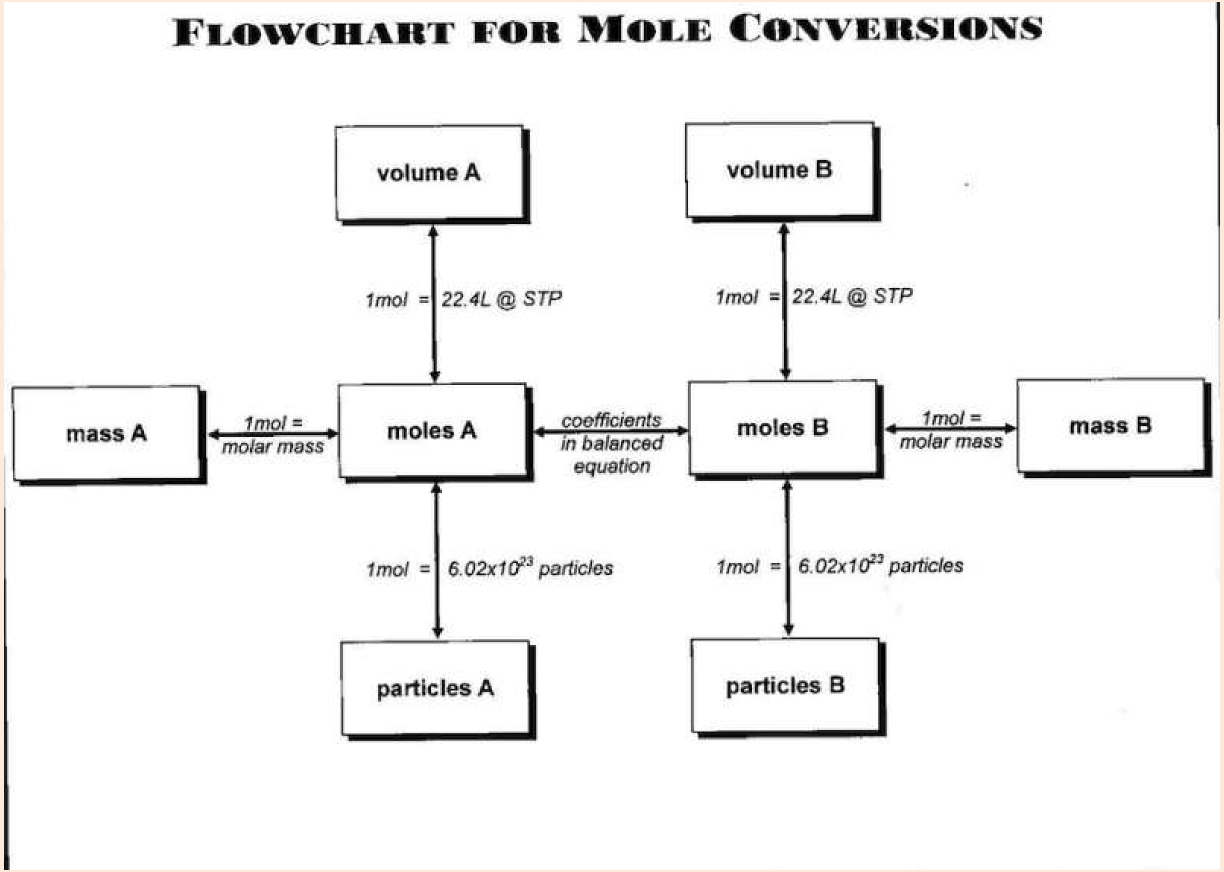
EX: Density of butane is 0.5788 g / mL

$$\frac{0.5788 \text{ g butane}}{1 \text{ mL butane}} \quad \text{OR} \quad \frac{1 \text{ mL butane}}{0.5788 \text{ g butane}}$$

<u>Mole-to-mole ratio:</u> the ratio of moles in a balanced chemical equation

Consider the reaction: $3O_2 \rightarrow 2O_3$

$$\frac{3 \text{ mol } O_2}{2 \text{ mol } O_3} \quad \text{OR} \quad \frac{2 \text{ mol } O_3}{3 \text{ mol } O_2}$$


FLOWCHART FOR MOLE CONVERSIONS
volume A
volume B
1mol = 22.4L @ STP
1mol = 22.4L @ STP
mass A
1mol = molar mass
moles A
coefficients in balanced equation
moles B
1mol = molar mass
mass B
1mol = 6.02x10^23 particles
1mol = 6.02x10^23 particles
particles A
particles B

Stoichiometry Practice

EX: Consider the following balanced chemical equation:

$$2N_2O(g) + 3O_2(g) \rightarrow 2N_2O_4(g)$$

How many grams of N_2O_4 can be produced from 27.8 g N_2O with **excess** oxygen?

Molar masses: N_2O = 44.013 g / mol N_2O_4 = 92.011 g / mol

27.8 g N_2O	1 mol N_2O	2 mol N_2O_4	92.011 g N_2O_4	= g N_2O_4
	44.013 g N_2O	2 mol N_2O	1 mol N_2O_4	

Stoichiometry Practice

Williamson Ether Synthesis

Consider the following chemical equation:

$$CH_3ONa + CH_3Cl \rightarrow NaCl + CH_3OCH_3$$

Sodium methoxide (CH_3ONa) reacts with methyl chloride (CH_3Cl) to form sodium chloride ($NaCl$) and dimethyl ether (CH_3OCH_3).

EX: Calculate the amount of CH_3OCH_3 produced in grams from 2.3 moles CH_3Cl and **excess** CH_3ONa.

2.3 mol CH_3Cl	1 mol CH_3OCH_3	46.07 g CH_3OCH_3
	1 mol CH_3Cl	1 mol CH_3OCH_3

= ____ g CH_3OCH_3

GRASPS Performance Task

Learning Targets:

I can use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction by calculating the mass of sulfuric acid produced from sulfur dioxide emissions.

I can determine the amount of sulfur in sulfur dioxide emissions by applying the mole-to-mole ratio.

I can determine the hazard level of a sample of acid rain by calculating the amount of sulfuric acid in that sample.

March 19, 2021