Tishk International University
Faculty of Applied Science
Department of Nutrition & Dietetics

Spring 2026

General Chemistry/ NUT 106

# Stoichiometry of Formulas & Equations

## 3rd Lecture

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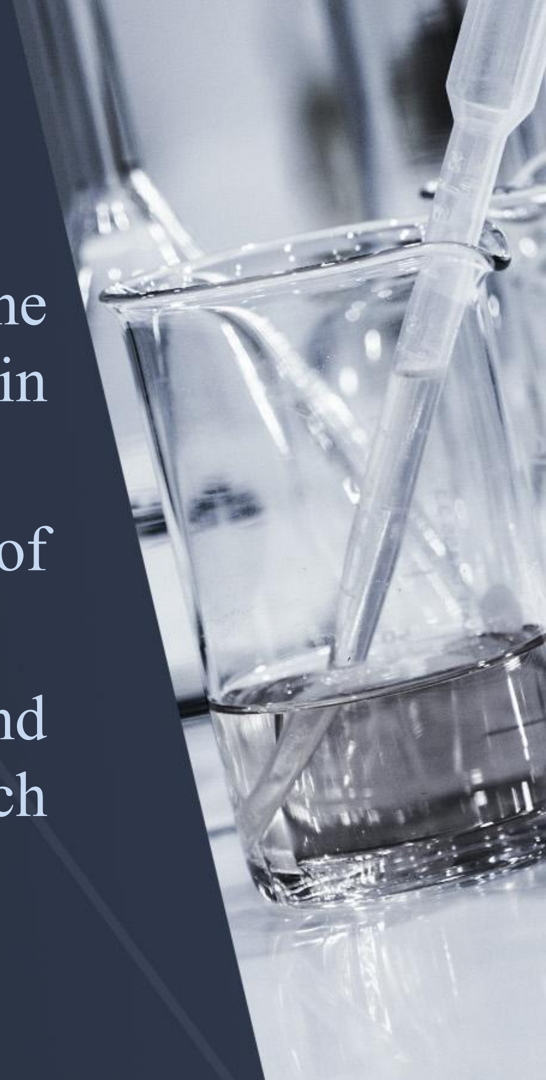
# The Chemical Equation

- A chemical equation is the representation of the reactants and products in a chemical reaction in terms of chemical symbols and formulas.
- The subscripts represent the number of atoms of an element in the compound.
- The coefficients in front of the compound represents the number of moles of each compound required to balance the equation.



# The Chemical Equation

A balanced equation will have an equal number of atoms of each element on both sides of equation.

Reactants Products

$N_2(g) + O_2(g) \rightarrow 2\,NO(g)$ (4 atoms on each side)

1 mole nitrogen + 1 mole oxygen yields 2 moles nitrogen monoxide

Phase representations in Chemical Equations

$\rightarrow$ = yields, or forms (g) = gas phase

(l) = liquid phase (s) = Solid phase

# The Chemical Equation

## Example Problem

Balance the following reaction;

$$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O$$

$$1\ C_8H_{18} + O_2 \rightarrow 8\ CO_2 + H_2O$$

$$1\ C_8H_{18} + O_2 \rightarrow 8\ CO_2 + 9\ H_2O$$

$$1\ C_8H_{18} + {}^{25/2}\ O_2 \rightarrow 8CO_2 + 9\ H_2O$$

$$2\ C_8H_{18} + 25\ O_2 \rightarrow 16\ CO_2 + 18\ H_2O$$

# Stoichiometry in Chemical Equations

Stoichiometry – calculation of the quantities of reactants and products in a chemical reaction.

Example: air oxidation of Methane to form Ozone (pollutant) and Hydroxyl radical (OH •)

| | $CH_4$ | + 10 $O_2$ → | $CO_2$ + | $H_2O$ + | 5 $O_3$ + | 2 OH • |
|---|---|---|---|---|---|---|
| molecules | 1 | 10 | 1 | 1 | 5 | 2 |
| moles | 1 | 10 | 1 | 1 | 5 | 2 |
| Total Mass | 16.0g | 320g | 44.0g | 18.0g | 240g | 34.0g |

1 mole = $6.022 \times 10^{23}$ molecules (Avogadros No.)

1 mole $CH_4$ is stoichiometrically equivalent to 10 moles ($O_2$)

1 mole $CH_4$ is stoichiometrically equivalent to 1 mole $CO_2$

# Stoichiometry in Chemical Equations

When Dinitrogen Pentoxide, $N_2O_5$, a while solid, is heated, it decomposes to Nitrogen Dioxide and Oxygen

$$2\ N_2O_5(s) \longrightarrow 4\ NO_2(g) + O_2(g)$$

Molar Ratio 2 : 4 : 1

# Stoichiometry in Chemical Equations

How many grams of HCl are required to react with 5.00 grams Manganese Dioxide ($MnO_2$) according to the equation?

$4\ HCl(aq) + MnO_2(s) \rightarrow 2\ H_2O(l) + MnCl_2(aq) + Cl_2(g)$

Strategy: 1. Determine the Molar Ratio of HCl to $MnO_2$

2. Compute the no. moles $MnO_2$ actually used

3. Use actual moles $MnO_2$ & Molar ratio to compute mass HCl

Molar Ratio HCl : $MnO_2$ = 4 : 1

5.00 g $MnO_2$ x (1 mol $MnO_2$/86.9368 g $MnO_2$) = 0.575 mol $MnO_2$

0.575 mol $MnO_2$ x (4 mol HCl/1 mol $MnO_2$) x (36.461 g HCl/mol HCl) = 8.39 g HCl

# Limiting Reactants and Yields

Theoretical Yield & Percent Yield

**The Theoretical Yield**, in grams, is computed from the number of moles of the "Limiting Reagent", the Stoichiometric Molar Ratio, and the Molecular Weight of the product

Yield = mol (Lim)x Mol Ratio Prod/Lim x Mol Wgt Product

The Percent Yield of a product obtained in a "Synthesis" experiment is computed from the amount of product actually obtained in the experiment and the Theoretical Yield

% Yield = Actual Yield / Theoretical Yield x 100

Note: The yield values can be expressed in either grams or moles

# Example Yield Calculation

Hydrogen ($H_2$) is a possible clean fuel because it reacts with Oxygen (O) to form non-polluting water ($H_2O$)

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

If the yield of this reaction is 87% what mass of Oxygen is required to produce 105 kg of Water?

Molar Ratio: 2 mol $H_2$ reacts with 1 mol $O_2$ to form 2 mol Water ($H_2O$)

Moles $H_2O$: 105 kg $H_2O$ x (1000g/1 kg) x (1 mol $H_2O$/18.01 g/mol $H_2O$)

= 5,830 mol $H_2O$

Moles $O_2$ = (1 mol $O_2$/2 mol $H_2O$) x 5,830 mol $H_2O$ = 2,915 mol $O_2$

Mass $O_2$ = 2,915 mol $O_2$ x (32.0 g $O_2$ / 1 mol $O_2$) x (1 kg/1000 g)

= 93.2 kg $O_2$ required to produce 105 kg $H_2O$ (100%)

At 87% efficiency: 93.2 kg x 100%/87% = 107 kg $O_2$ required

# Solution Stoichiometry

Solute – A substance dissolved in another substance

Solvent – The substance in which the "Solute" is dissolved

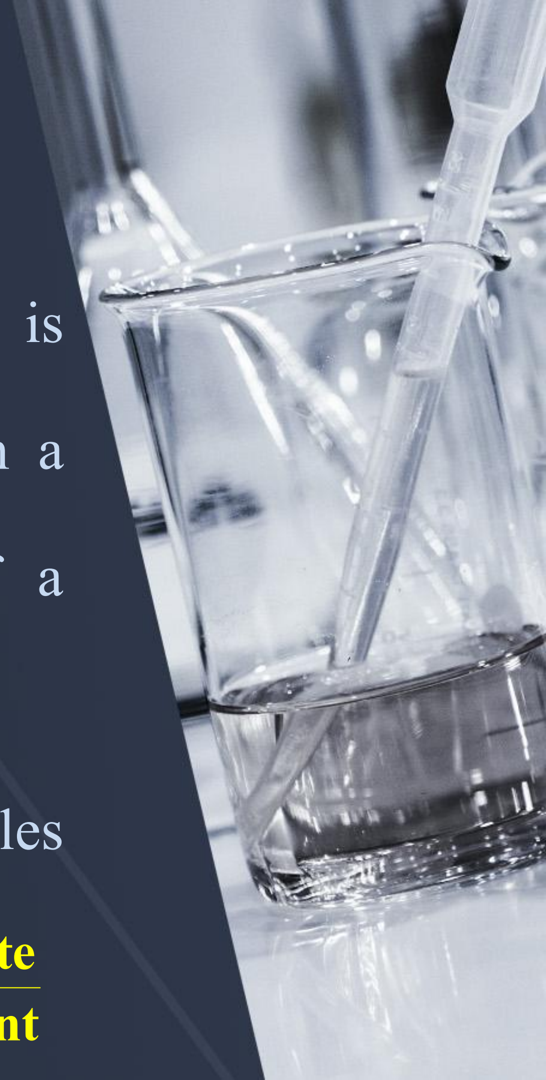
Concentration – The amount of solute dissolved in a given amount of solvent

Molarity (M) – Expresses the concentration of a solution in units of moles solute per liter of solution

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liters of solution}} \qquad M = \frac{\text{mol solute}}{\text{L soln}}$$

Molality (m) – Expresses the number of moles dissolved in 1000g (1KG) of solvent.

$$\text{Molality} = \frac{\text{Moles Solute}}{\text{Kilogram Solvent}} = m = \frac{\text{mol solute}}{\text{Kg solvent}}$$



# Solution Volume vs. Solvent Volume

The Volume term in the denominator of the molarity expression is the solution volume not the volume of the solvent.

1 mole of solute dissolved in 1 Liter of a solvent does not produce a 1 molar (M) solution.

The Mass term in the denominator of the molality expression is the Mass of solvent.

# Solution Stoichiometry

(Mole – Mass) Conversions involving Solutions

Calculating the Mass of a substance given the Volume and Molarity

Ex. How many grams of Sodium Hydrogen Phosphate ($Na_2HPO_4$) are in 1.75 L of a 0.460 M solution?

Moles $Na_2HPO_4$ = 1.75 L x 0.460 mol $Na_2HPO_4$/1 L soln

=0.805 mol $Na_2HPO_4$

Mass $Na_2HPO_4$ = 0.805 mol x 141.96 g $Na_2HPO_4$/mol $Na_2HPO_4$

= 114. g

# Practice Problem

- Calculate the volume of a 3.30 M Sucrose solution containing 135 g of solute.

(FW Sucrose – 342.30 g/mol)

Ans:

<u>moles solute</u>

135 g sucrose x 1 mol sucrose / 342.30 g sucrose = 0.3944 mol

<u>Vol soln</u>

0.3944 mol sucrose x 1.00 L solution/3.30 mol sucrose = 0.120 L

# Dilution

- The amount of solute in a solution is the same after the solution is diluted with additional solvent
- Dilution problems utilize the following relationship between the molarity (M) and volume (V)

$$M_{dil} \times V_{dil} = \text{number of moles} = M_{conc} \times V_{conc}$$

# Practice Problem

Calculate the Molarity of the solution prepared by diluting 37.00 mL of 0.250 M Potassium Chloride (KCl) to 150.00 mL.

Ans: Dilution problem (M1V1 = M2V2)

M1 = 0.250 M KCl V1 = 37.00 mL

M2 = ? V2 = 150.00 mL

M1V1= M2V2 THEREFORE M2 = M1V1 / V2

M2 = (0.250 M) x 37.00 mL) / 150.0 mL

= 0.0617 M

# Practice Problem

How many liters (L) of stomach acid (0.10 M HCl) react with (neutralize) 0.10 grams (g) of Magnesium Hydroxide (antacid)

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Convert mass (g) of $Mg(OH)_2$ to moles

$$\text{mol } Mg(OH)_2 = 0.1 \text{ g } Mg(OH)_2 \times \frac{1 \text{ mol } Mg(OH)_2}{58.33 \text{ g } Mg(OH)_2} = 1.7 \times 10^{-3} \text{ mol}$$

Convert from moles of $Mg(OH)_2$ to moles of HCl

$$\text{mol HCl} = 1.7 \times 10^{-3} \text{ mol } Mg(OH)_2 \times \frac{2 \text{ mol HCl}}{1 \text{ mol } Mg(OH)_2} = 3.4 \times 10^{-3} \text{ mol HCl}$$

Convert moles HCl to volume (L)

$$\text{Vol (L) HCL} = 3.4 \times 10^{-3} \text{ mol HCl} \times \frac{1\text{L}}{0.10 \text{ mol HCl}} = 3.4 \times 10^{-2} \text{ L}$$

# Equation summary

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liters of solution}} \qquad M = \frac{\text{mol solute}}{\text{L soln}}$$

$$\text{Molality} = \frac{\text{Moles Solute}}{\text{Kilogram Solvent}} \qquad m = \frac{\text{mol solute}}{\text{Kg solvent}}$$

$$M_{dil} \times V_{dil} = \text{number of moles} = M_{conc} \times V_{conc}$$