

12: Stoichiometry

Key Stoichiometry Terms

- Stoichiometry:** Using the mole ratio in the balanced equation and information about one compound to find information about another in the reaction.
- Dimensional Analysis:** Method of converting units by multiplying by ratio of equalities.
- Molar Mass:** Sum of all the atomic masses (from the periodic table) in the compound.
- Solute:** Substance being dissolved in a homogeneous mixture (solution).
- Concentration:** Measure of how much solute is dissolved in how much solution.
- Molarity (M):** A concentration unit in moles per unit liter.
- Standard Temperature and Pressure (STP):** 1 atm (or 101.3 kPa) and 273 K (0°).
- Molar Volume of a Gas:** 1 mole of any gas at STP is 22.4 liters.
- Limiting Reactant:** Reactant that stops the reaction by running out first.
- Actual Yield:** The amount actually produced in the lab.
- Theoretical Yield:** Amount that should be theoretically produced based on stoichiometric calculations.
- Percent Yield:** Compares the actual yield to the theoretical yield (their ratio with %).

Chemical Equations

- Coefficients give the mole ratios.

Example:

$2 \text{H}_2 (\text{g}) + \text{O}_2 (\text{g}) \rightarrow 2 \text{H}_2\text{O} (\text{l})$
2 moles of H_2 react with 1 mole of O_2 and produces 2 moles of H_2O .

Dimensional Analysis in Stoichiometry

Equalities used during dimensional analysis for stoichiometry:

- Mole ratio in balanced equation:** Use to convert between moles of different compounds in the balanced equation.
- Molar mass:** Used to convert between grams and moles.
- Concentration:** Used to convert between moles and liters of a solution.
- Molar volume of a gas:** Used to convert between moles and liters of a gas at STP.

KUDOS for Stoichiometric Problems

Method to solve word problems:

- K = Known.** Identify all the known information (given quantities, balanced equation, etc.).
- U = Unknown.** What quantity and what compound does the problem ask for?
- D = Definition.** Identify the equalities that will be needed during dimensional analysis to convert from the known to the unknown.
- O = Output.** Perform the dimensional analysis.
- S = Substantiation.** Check for reasonableness, units and correct significant figures.

Molarity

Molarity - the concentration measure by the moles of solute per liter of solution.

$$\text{Molarity} = \frac{\text{moles solute}}{\text{L solution}}$$

Limiting Reactants

- Once a reactant has run out, the reaction will stop.
 - Do stoichiometry for each given reactant quantity to the same product each time. Choose the calculation that gives the **smallest amount** of product.
 - The reactant that produced the smallest amount of product is the **limiting reactant**.
 - Steps to determine the limiting reactant: grams reactant $\rightarrow$ moles reactant $\rightarrow$ moles product $\rightarrow$ grams product. Alternatively, use the m/c method below.
- Simple Limiting Reagent Finder Mnemonic:** Find the moles of each reactant and divide the moles of each reactant by its coefficient. The reactant with the smallest number is the limiting reagent = "Smallest m/c is limited".

Percent Yield

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

Example:

If stoichiometry calculations tell you that a reaction should produce 10.5 g, but when you perform the lab you produce 8.7 g, what was the percent yield?

$$\% \text{ yield} = \frac{8.7 \text{ g}}{10.5 \text{ g}} \times 100 = 82.9\%$$

Stoichiometry Examples

All examples for the following reaction:



Mole-Mass example:

0.75 moles HCl react. How many grams Mg are needed?

$$\frac{0.75 \text{ mole HCl}}{2 \text{ mole HCl}} \times \frac{1 \text{ mole Mg}}{1 \text{ mole HCl}} \times \frac{24.31 \text{ g Mg}}{1 \text{ mole Mg}} = 9.1 \text{ g Mg}$$

Mass-Mass example:

If 2.5 g Mg react, how many grams MgCl_2 are produced?

$$\frac{2.5 \text{ g-Mg}}{24.31 \text{ g-Mg}} \times \frac{1 \text{ mole-Mg}}{1 \text{ mole-Mg}} \times \frac{1 \text{ mole-MgCl}_2}{1 \text{ mole-Mg}} \times \frac{95.21 \text{ g-MgCl}_2}{1 \text{ mole-MgCl}_2} = 9.8 \text{ g MgCl}_2$$

Mass-Liter example (solution):

How many liters of 1.7 M HCl are needed to react with 2.5 g Mg?

$$\frac{2.5 \text{ g Mg}}{24.31 \text{ g Mg}} \times \frac{1 \text{ mole-Mg}}{1 \text{ mole-Mg}} \times \frac{2 \text{ mole-HCl}}{1 \text{ mole-Mg}} \times \frac{1 \text{ L HCl}}{1.7 \text{ mole HCl}} = 0.12 \text{ L HCl}$$

Mass-Liter example (gas):

How many liters of H_2 are produced when 3.5 g Mg react?

$$\frac{3.5 \text{ g-Mg}}{24.31 \text{ g-Mg}} \times \frac{1 \text{ mole-Mg}}{1 \text{ mole-Mg}} \times \frac{1 \text{ mole-H}_2}{1 \text{ mole-Mg}} \times \frac{22.4 \text{ L H}_2}{1 \text{ mole H}_2} = 3.2 \text{ L H}_2$$

Limiting reactant:

If 0.25 mole HCl reacts with 0.55 mole Mg, how many grams of MgCl_2 are produced and what was the limiting reactant?



$$\frac{0.25 \text{ mole HCl}}{2 \text{ mole HCl}} \times \frac{1 \text{ mole-MgCl}_2}{1 \text{ mole HCl}} \times \frac{95.21 \text{ g-MgCl}_2}{1 \text{ mole-MgCl}_2} = 12 \text{ g MgCl}_2$$

(less)

$$\frac{0.55 \text{ mole-Mg}}{1 \text{ mole-Mg}} \times \frac{1 \text{ mole-MgCl}_2}{1 \text{ mole-Mg}} \times \frac{95.21 \text{ g-MgCl}_2}{1 \text{ mole-MgCl}_2} = 52 \text{ g MgCl}_2$$

12 g MgCl_2 will be produced and HCl is the limiting reactant.

How to Use This Cheat Sheet: These are the keys related to this topic. Try to read through it carefully twice then write it out from memory on a blank sheet of paper. Review it again before the exams.

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Arthur Halpern, George McBane



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