Application of Mass Relationship in Chemical Reaction

Introduction

Chemistry is not just about observing color changes or explosions; it is a quantitative science. To produce a specific amount of medicine or fuel, chemists must calculate exactly how much of each reactant is needed.

- This branch of chemistry is called **Stoichiometry**.
- It deals with the mass relationships between reactants and products in a chemical reaction.
- It is based on the Law of Conservation of Mass: matter cannot be created or destroyed, only rearranged.

Learning Objectives

By the end of this module, you will be able to:

- Describe quantitative chemical reactions and the principles of conservation of mass.
- Perform calculations involving mass relationships, specifically stoichiometry.
- Convert between mass, moles, and number of particles using the mole concept.
- Calculate percent composition of compounds.
- Balance chemical equations to accurately represent chemical changes.

Key Concepts and Definitions

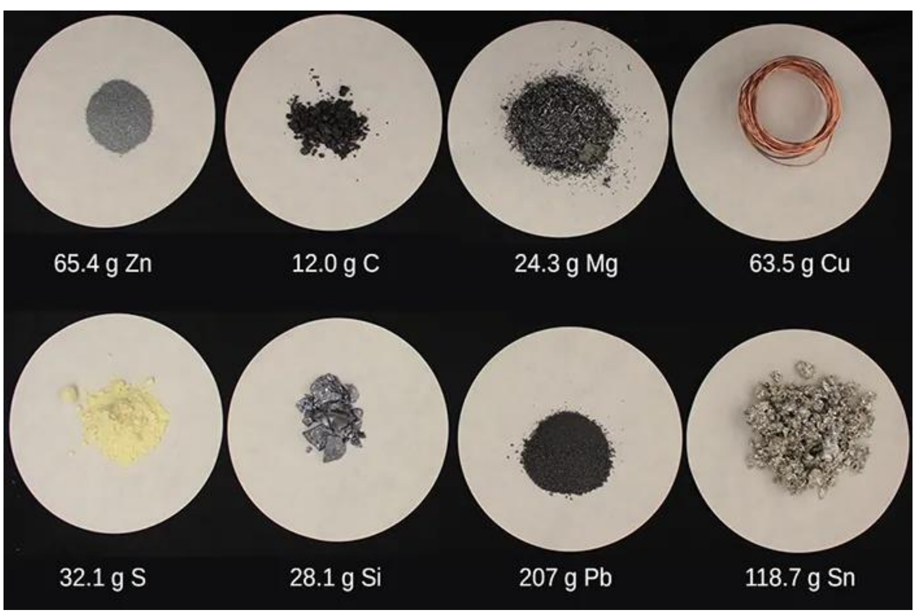
Term	Definition
Stoichiometry	The calculation of quantities of reactants and products involved in a chemical reaction.

The Mole (mol)	The SI unit for amount of substance. One mole contains 6.022 x 10^23 particles.
Avogadro's Number	The number of particles in one mole: 6.022 x 10^23.
Molar Mass	The mass of one mole of a substance (in grams/mole), numerically equal to atomic mass.
Limiting Reactant	The reactant that is completely consumed first, limiting the amount of product formed.
Percent Yield	The ratio of the actual yield (from experiment) to the theoretical yield (from calculation).

Detailed Discussion

The Mole Concept and Molar Mass

Atoms and molecules are too small to count individually. To solve this, chemists use a counting unit called the **Mole**. Just as a "dozen" represents 12 items, a "mole" represents a specific (very large) number of particles.



A. Avogadro's Number One mole of any substance contains exactly **6.022×10^{23}** particles (atoms, molecules, or ions).

- *Example:* 1 mole of Carbon-12 atoms has a mass of exactly 12 grams and contains 6.022×10^{23} atoms.

B. Molar Mass The molar mass is the mass of one mole of a substance, expressed in grams per mole (g/mol). It allows us to convert between mass (which we can measure on a balance) and moles (which represents the count of particles).

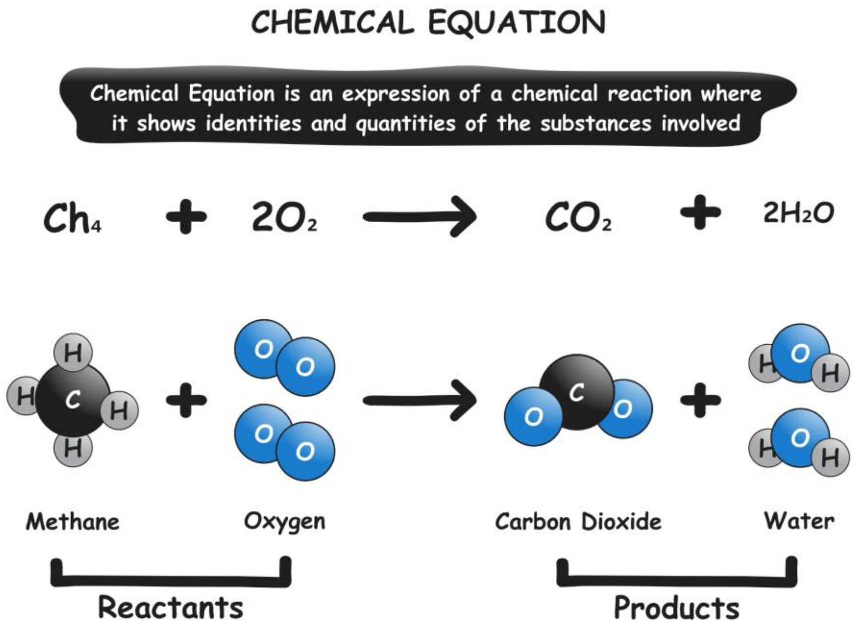
- **For Elements:** Look at the Periodic Table. The atomic mass of Carbon is 12.01 amu, so its Molar Mass is 12.01 g/mol.
- **For Compounds:** Sum the atomic masses of all atoms in the formula.
    - *Example (Water, H_2O):* (2 * 1.008 g/mol H) + (1 * 16.00 g/mol O) = 18.016 g/mol.

C. Mole Conversions The central calculation in chemistry involves these conversions:

- **Mass to Moles:** Moles = Mass (g) / Molar Mass (g/mol)
- **Moles to Mass:** Mass (g) = Moles * Molar Mass (g/mol)
- **Moles to Particles:** Particles = Moles * Avogadro's Number

Chemical Equations and Balancing

A chemical equation is a written representation of a chemical reaction. Because matter is conserved, the number of atoms of each element must be the same on both sides of the equation.



A. Components of an Equation

- **Reactants:** Starting materials (left side).
- **Products:** Substances formed (right side).
- **Coefficients:** Large numbers placed *in front* of formulas to balance the equation. (e.g., **2**H2O). You change coefficients, never subscripts.

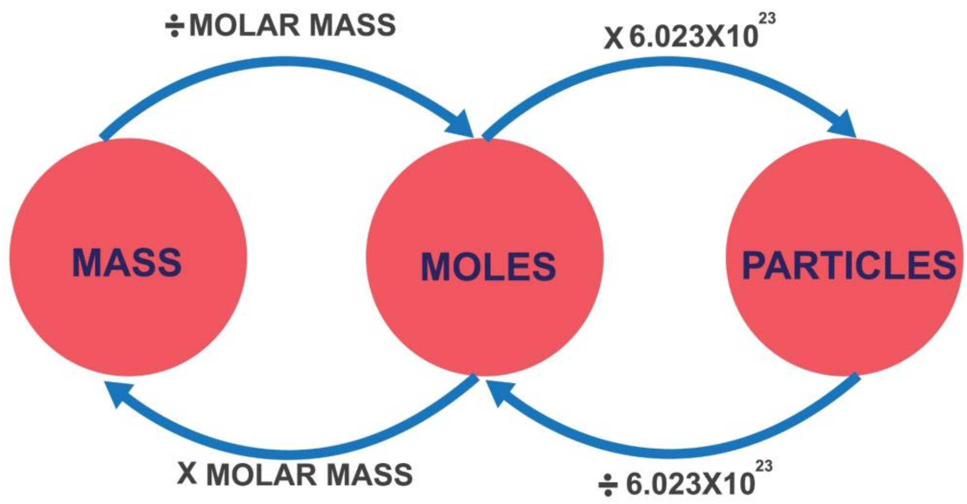
B. Steps to Balance:

1. Count the atoms of each element on the Reactant side and Product side.
2. Change coefficients to make the numbers equal.
3. *Tip:* Balance Hydrogen and Oxygen last, as they often appear in multiple compounds.

- *Example:*
  - Unbalanced: H2 + O2 -> H2O (2 H, 2 O -> 2 H, 1 O)
  - Balanced: **2**H2 + O2 -> **2**H2O (4 H, 2 O -> 4 H, 2 O)

Stoichiometric Calculations

Stoichiometry uses the **Mole Ratio** derived from a balanced chemical equation to convert between reactants and products. This is the "recipe" conversion.



The General Flow:

1. **Grams of A -> Moles of A:** Divide known mass by Molar Mass of A.
2. **Moles of A -> Moles of B:** Use the Mole Ratio from the coefficients of the balanced equation (Coefficient B / Coefficient A).
3. **Moles of B -> Grams of B:** Multiply Moles of B by Molar Mass of B.

- *Analogy:* If a sandwich recipe (equation) requires 2 slices of bread and 1 slice of cheese to make 1 sandwich, and you have 20 slices of bread, you can calculate that you can make 10 sandwiches (provided you have enough cheese).

Percent Composition

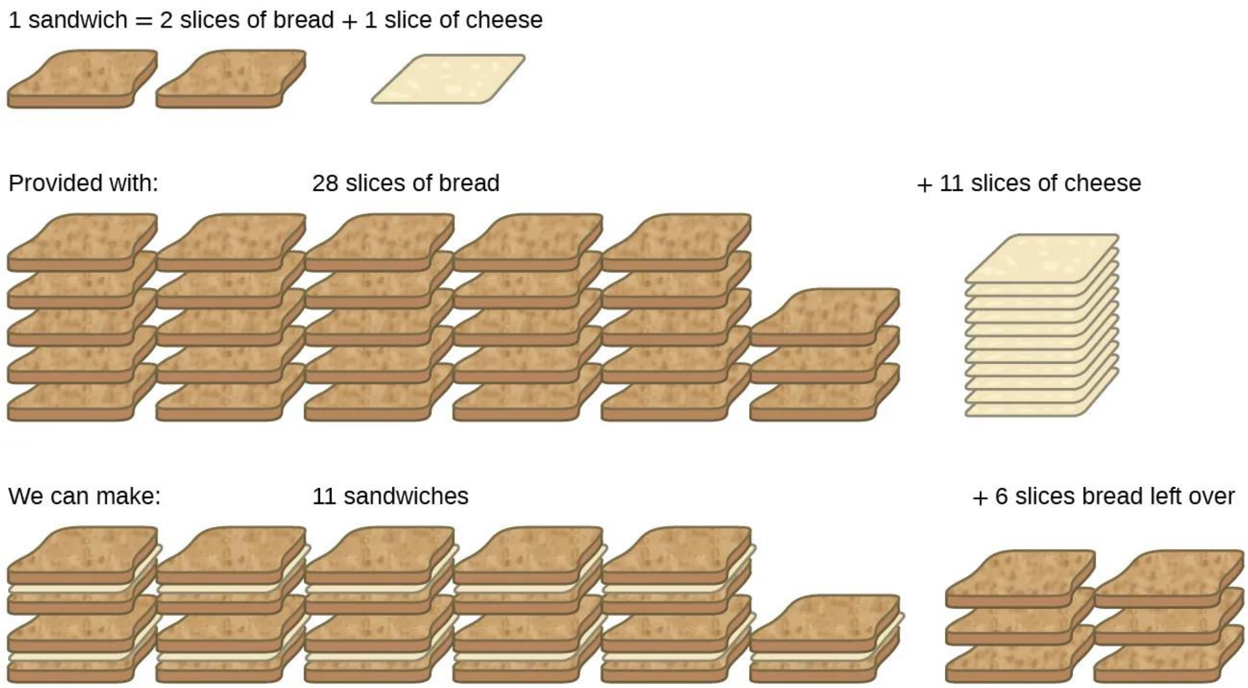
Percent composition tells us the percentage by mass of each element in a compound.

Formula: % Element = (Mass of Element in formula / Total Molar Mass of Compound) * 100

- *Example: Percent of H in Water (H_2O)*
  - Mass of H: 2 * 1.008 = 2.016 g/mol
  - Total Mass of H_2O: 18.016 g/mol
  - Calculation: (2.016 / 18.016) * 100 = **11.2% Hydrogen**

Limiting Reactants

In real-world reactions, reactants are rarely present in perfect stoichiometric ratios. Usually, one runs out first.



- **Limiting Reactant:** The reactant that is used up first. It limits the amount of product that can be formed.
- **Excess Reactant:** The reactant left over after the reaction stops.

How to find it:

1. Calculate how much product *Reactant A* could make.
2. Calculate how much product *Reactant B* could make.
3. The reactant that produces the **smaller** amount of product is the Limiting Reactant.

References

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