Basic Chemistry Concepts

Lecture Notes on Stoichiometric Calculations and Related Concepts

Stoichiometric Calculations

Definition: Stoichiometry is the calculation of reactants and products in chemical reactions. It is based on the balanced chemical equation and the conservation of mass.

Key Steps in Stoichiometric Calculations:

1. **Write and Balance the Chemical Equation**:
    - Ensure the number of atoms of each element is the same on both sides of the equation.

   Example:

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

2. **Convert Masses to Moles**:
    - Use molar masses of reactants to convert given masses to moles.
3. **Use Mole Ratios**:
    - Use the coefficients from the balanced equation to set up mole ratios.
4. **Calculate Moles of Desired Substance**:
    - Use mole ratios to calculate the moles of the product or another reactant.
5. **Convert Moles Back to Mass**:
    - Convert the moles of the desired substance back to grams if needed.

Limiting Reactant

Definition: The limiting reactant (or limiting reagent) is the reactant that is completely consumed in a reaction, determining the maximum amount of product that can be formed.

Steps to Identify the Limiting Reactant:

1. **Calculate the Moles of Each Reactant**:
    - Convert the given masses of reactants to moles.
2. **Use Stoichiometry to Find Required Moles**:
    - Determine the mole ratio from the balanced equation.
3. **Compare the Calculated Moles**:

- The reactant that produces the least amount of product is the limiting reactant.

Example:
For the reaction: $N_2 + 3H_2 \rightarrow 2NH_3$

- If 5 moles of N_2 and 12 moles of H_2 are available:
  - 5 moles N_2 requires $5 \times 3 = 15$ moles of H_2.
  - Only 12 moles H_2 are available, so H_2 is the limiting reactant.

Yield of Reaction

Theoretical Yield:

- **Definition**: The maximum amount of product that can be produced from a given amount of reactants, calculated using stoichiometry.
- **Calculation**: Based on the limiting reactant.

Actual Yield:

- **Definition**: The amount of product actually obtained from a reaction.
- **Measurement**: Determined experimentally.

Percent Yield:

- **Definition**: The ratio of the actual yield to the theoretical yield, expressed as a percentage.
- **Formula**:

$$\text{Percent Yield} = \left(\frac{\text{Actual Yield}}{\text{Theoretical Yield}}\right) \times 100$$

Example:
If the theoretical yield of a reaction is 10 grams and the actual yield is 8 grams:

$$\text{Percent Yield} = \left(\frac{8\text{ g}}{10\text{ g}}\right) \times 100 = 80\%$$

Example Problem

Given the reaction: $2H_2 + O_2 \rightarrow 2H_2O$

1. **Calculate the theoretical yield of water when 4 grams of H_2 react with 16 grams of O_2**:
   - Molar mass of H_2 = 2 g/mol
   - Moles of H_2 = $\frac{4\text{ g}}{2\text{ g/mol}} = 2$ moles
   - Molar mass of O_2 = 32 g/mol
   - Moles of O_2 = $\frac{16\text{ g}}{32\text{ g/mol}} = 0.5$ moles
   - Reaction ratio: 2 mol H_2 : 1 mol O_2

$$O_2 \text{ is the limiting reactant}$$

   - Theoretical yield of H_2O: $2 \text{ moles } O_2 \rightarrow 2 \times 2 = 4 \text{ moles } H_2O$

- Mass of H_2O: $4 \times 18 \text{ g/mol} = 72 \text{ g}$

2. **Determine the actual yield and percent yield if 68 grams of H_2O were produced**:
    - Actual yield = 68 grams
    - Theoretical yield = 72 grams
    - Percent yield:

$$\text{Percent Yield} = \left(\frac{68}{72}\right) \times 100 \approx 94.44\%$$

Summary

- **Stoichiometric Calculations**: Convert between masses and moles using balanced equations.
- **Limiting Reactant**: Determines the maximum product formed.
- **Theoretical Yield**: Maximum calculated product.
- **Actual Yield**: Measured product.
- **Percent Yield**: Efficiency of a reaction, comparing actual to theoretical yields.

These notes provide a comprehensive understanding of stoichiometry, limiting reactants, and reaction yields, essential for mastering chemical reaction calculations.