Basic Chemistry Concepts

Lecture Notes on Percentage Composition and Empirical and Molecular Formulae

Percentage Composition

Calculation of Percentage Composition

- **Definition**: Percentage composition of a compound is the percent by mass of each element in the compound.
- **Formula**:

$$\text{Percentage composition} = \left(\frac{\text{Mass of element in 1 mole of compound}}{\text{Molar mass of compound}}\right) \times 100$$

- **Example**: Calculate the percentage composition of water (H_2O).
  - Molar mass of H_2O = 2(1.008) + 16.00 = 18.016 g/mol
  - Mass of hydrogen in 1 mole of H_2O = 2(1.008) = 2.016 g
  - Mass of oxygen in 1 mole of H_2O = 16.00 g
  - Percentage of hydrogen:

$$\left(\frac{2.016}{18.016}\right) \times 100 \approx 11.19\%$$

  - Percentage of oxygen:

$$\left(\frac{16.00}{18.016}\right) \times 100 \approx 88.81\%$$

Applications of Percentage Composition

- **Determining Empirical Formulas**: The simplest ratio of elements in a compound can be deduced from the percentage composition.
- **Quality Control in Manufacturing**: Ensuring that the correct proportions of elements are present in a product.
- **Nutritional Information**: Calculating the nutritional content of food based on its chemical composition.
- **Environmental Analysis**: Determining the concentration of pollutants in air, water, or soil samples.

Empirical and Molecular Formulae

Definition of Empirical Formula

- **Empirical Formula**: The simplest whole-number ratio of atoms of each element in a compound.
  - **Example**: The empirical formula of hydrogen peroxide (H_2O_2) is HO.

Definition of Molecular Formula

- **Molecular Formula**: The actual number of atoms of each element in a molecule of the compound.
  - **Example**: The molecular formula of hydrogen peroxide is H_2O_2.

Calculation of Empirical and Molecular Formulae

- **Steps to Calculate Empirical Formula**:

  1. **Determine the mass of each element in the compound**: If given percentages, assume 100 grams of the compound.
  2. **Convert masses to moles**: Use the molar mass of each element.
  3. **Find the simplest ratio**: Divide all mole values by the smallest number of moles calculated.
  4. **Multiply to obtain whole numbers**: If necessary, multiply the ratios by a common factor to get whole numbers.

  - **Example**: A compound contains 40% carbon, 6.67% hydrogen, and 53.33% oxygen by mass.
    - Masses: 40 g C, 6.67 g H, 53.33 g O
    - Moles: $\frac{40}{12.01} \approx 3.33$ mol C, $\frac{6.67}{1.008} \approx 6.62$ mol H, $\frac{53.33}{16.00} \approx 3.33$ mol O
    - Ratios: 3.33 mol C, 6.62 mol H, 3.33 mol O (simplify by dividing by 3.33)
    - Empirical formula: CH_2O

- **Steps to Calculate Molecular Formula**:

  1. **Determine the empirical formula**.
  2. **Calculate the empirical formula mass**: Sum of the atomic masses in the empirical formula.
  3. **Determine the molar mass of the compound**: Given or experimentally determined.
  4. **Divide the molar mass by the empirical formula mass**: This gives a multiplication factor.
  5. **Multiply the empirical formula by this factor**: To get the molecular formula.

  - **Example**: Empirical formula CH_2O, molar mass = 180 g/mol.
    - Empirical formula mass = 12.01 (C) + 2(1.008) (H) + 16.00 (O) = 30.03 g/mol
    - Factor = $\frac{180}{30.03} \approx 6$
    - Molecular formula = $C_6H_{12}O_6$

Relationship between Empirical and Molecular Formulae

- The molecular formula is a whole-number multiple of the empirical formula.
  - **Example**: For benzene, the empirical formula is CH, and the molecular formula is C_6H_6 (a multiple of 6).

Summary

- **Percentage Composition**: Provides the mass percentage of each element in a compound, useful for determining empirical formulas and various applications in industry and research.
- **Empirical Formula**: The simplest ratio of elements in a compound.
- **Molecular Formula**: The actual number of atoms of each element in a compound, derived from the empirical formula and the compound's molar mass.
- **Calculations**: Involving percentage composition and conversion between empirical and molecular formulas, essential for chemical analysis and synthesis.

These notes cover the fundamental concepts and calculations related to percentage composition and empirical and molecular formulae, providing a solid foundation for understanding chemical compositions and formulae.