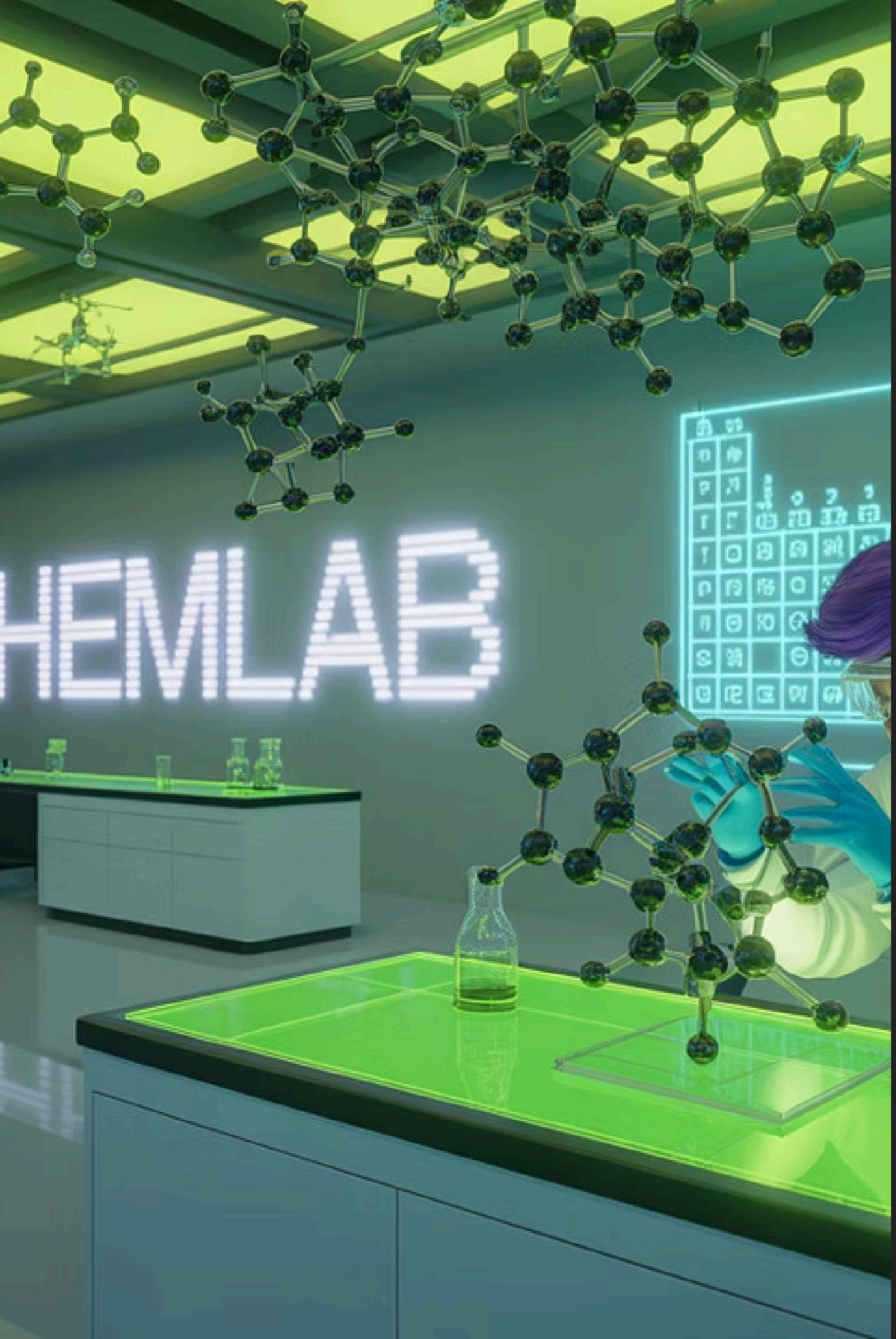

Chemistry Fundamentals

Lecture 16: Chemical Formulas and Nomenclature

Mohamed Kamal

Types of Chemical Formulas

1

Empirical Formula

Simplest whole number ratio of elements

Example: CH_2O (formaldehyde, glucose)

Used for: Composition analysis

2

Molecular Formula

Actual number of atoms in a molecule

Example: $C_6H_{12}O_6$ (glucose), CH_2O (formaldehyde)

Used for: Molar mass calculations

3

Structural Formula

Shows how atoms are connected

Example: H-O-H for water

Used for: Understanding reactivity and properties

Key Relationship: Molecular formula = (empirical formula) × n, where n is whole number

Determining Empirical Formulas from Percent Composition

Step-by-Step Process:

1. Assume 100 g sample (makes % = mass in grams)
2. Convert mass to moles for each element
3. Divide by smallest number of moles
4. Multiply by integer to get whole numbers if needed

Common Challenge: When ratios aren't whole numbers, multiply by 2, 3, or 4

Real-World Application: Quality control in pharmaceutical manufacturing

Worked Example: 40.0% C, 6.7% H, 53.3% O

Step 1: 40.0 g C, 6.7 g H, 53.3 g O

Step 2:

- C: 40.0 g ÷ 12.01 g/mol = 3.33 mol
- H: 6.7 g ÷ 1.008 g/mol = 6.6 mol
- O: 53.3 g ÷ 15.999 g/mol = 3.33 mol

Step 3: Divide by 3.33: $C_1H_2O_1$

Step 4: Empirical formula = CH_2O

From Empirical to Molecular Formula

Find empirical formula mass

Calculate the mass of the empirical formula using atomic masses

Divide molecular mass by empirical mass

This gives you the ratio (n) between molecular and empirical formulas

Multiply empirical formula by this ratio

This gives you the molecular formula

Example 1: Glucose

Empirical formula: CH_2O

Molecular mass: 180.16 g/mol

Empirical mass: 30.03 g/mol

Ratio = 180.16 ÷ 30.03 = 6.00

Molecular formula = $C_6H_{12}O_6$

Example 2: Formaldehyde

Empirical formula: CH_2O

Molecular mass: 30.03 g/mol

Empirical mass: 30.03 g/mol

Ratio = 30.03 ÷ 30.03 = 1.00

Molecular formula = CH_2O

Key Insight: Same empirical formula can represent different compounds

Naming Binary Ionic Compounds

Definition

Compounds containing metal cation + nonmetal anion

Naming Rules

1. Name metal first (unchanged)
2. Name nonmetal second with -ide ending
3. Include Roman numeral if metal has multiple oxidation states

Examples

Simple: NaCl (sodium chloride), MgO (magnesium oxide), Al_2O_3 (aluminum oxide)

With Roman numerals: $FeCl_2$ (iron(II) chloride), $FeCl_3$ (iron(III) chloride), $CuSO_4$ (copper(II) sulfate)

Memory Aid: "Metal first, nonmetal -ide, Roman numeral if metal can slide"

Polyatomic Ions - Recognizing and Naming

Definition: Groups of atoms that behave as single ions

Common Polyatomic Ions

OH^-	hydroxide
NO_3^-	nitrate
SO_4^{2-}	sulfate
CO_3^{2-}	carbonate
PO_4^{3-}	phosphate
NH_4^+	ammonium

Naming Examples

- $Ca(OH)_2$: calcium hydroxide
- $Fe(NO_3)_3$: iron(III) nitrate
- $(NH_4)_2SO_4$: ammonium sulfate

Pattern Recognition

- -ate ending: more oxygen (SO_4^{2-} sulfate)
- -ite ending: less oxygen (SO_3^{2-} sulfite)

Naming Molecular Compounds

Definition: Compounds between nonmetals only

Greek Prefixes

mono- (1), di- (2), tri- (3), tetra- (4), penta- (5)

hexa- (6), hepta- (7), octa- (8), nona- (9), deca- (10)

Naming Rules

1. First element: use element name (omit mono- prefix)
2. Second element: use prefix + element name + -ide

Examples

CO: carbon monoxide

CO_2: carbon dioxide

N_2O_4: dinitrogen tetroxide

P_2O_5: diphosphorus pentoxide

Special Cases: H_2O: water (not dihydrogen monoxide), NH_3: ammonia (not nitrogen trihydride)

Common Errors: Using ionic naming rules for molecular compounds

Acids and Bases - Special Naming Rules

Binary Acids (H + nonmetal)

Formula: HX

Name: hydro___ic acid

Examples:

- HCl: hydrochloric acid
- HF: hydrofluoric acid

Oxyacids (H + polyatomic ion with oxygen)

From -ate ion: ___ic acid

From -ite ion: ___ous acid

Examples:

- HNO_3 (from NO_3^-): nitric acid
- HNO_2 (from NO_2^-): nitrous acid
- H_2SO_4 (from SO_4^{2-}): sulfuric acid

Bases: Usually contain OH^- or produce OH^- in solution

Examples: NaOH (sodium hydroxide), $Ca(OH)_2$ (calcium hydroxide)

Memory Device: "If it's -ate, make it -ic; if it's -ite, make it -ous"

Formula Writing from Names

1

Identify ions

Determine the cation and anion from the name

Example: Aluminum sulfate → Al^{3+} and SO_4^{2-}

2

Determine charges

Find the charge of each ion (memorize common ions)

Example: Al^{3+} has +3 charge, SO_4^{2-} has -2 charge

3

Balance charges

Use subscripts to make total charge zero

Example: Need 2 Al^{3+} and 3 SO_4^{2-} to balance

4

Write formula

Use parentheses for polyatomic ions when needed

Example: $Al_2(SO_4)_3$

For Molecular Compounds: Use prefixes directly as subscripts

Example: dinitrogen pentoxide → N_2O_5

Common Mistakes: Forgetting parentheses around polyatomic ions, not balancing charges properly

Next Lecture:

Introduction to Chemical Reactions

Mohamed Kamal