CHEM110 – Chapter 3
Chemical Reactions and Stoichiometry

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3.4 Empirical Formulae

New compounds are analysed to determine the mass percentages of the elements contained in a substance → from this we can obtain an …

EMPIRICAL FORMULA

3.4 Empirical Formulae

- The empirical formula is the simplest whole-number ratio of atoms within that compound.
- For example, butane has the formula:

C_4H_{10}

molecular formula

- However this isn't the simplest ratio as both 4 and 10 are divisible by 2. Hence butane has the empirical formula:

C_2H_5

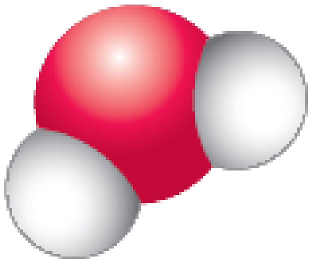
empirical formula

Mole Ratios from Chemical Formula

- **Consider water:**

chemical formula: H_2O

- **The chemical formula tells us the ratio of H atoms to O atoms is always 2 to 1**
- **For chemical compounds → mole ratios are the ratios of individual atoms**



  - **1 mole of water molecules contains 2 moles of H atoms and 1 mole of O atom**

Worked Example 3.4 – page 79

Leaves have a characteristic green colour due to the presence of the green pigment chlorophyll, which has the formula $C_{55}H_{72}MgNO_5$. A particular sample of chlorophyll was found to contain 0.0011 g of Mg. What mass of carbon was present in the sample?

Molar masses: C = 12.01 g mol^{-1} Mg = 24.31 g mol^{-1}

3.4 Empirical Formulae

- Chemists often make new compounds or isolate previously unknown compounds
- Compound can be decomposed to find the mass of each element experimentally
- These masses can be used to determine the formula of the compound

3.4 Empirical Formulae

- **The relative masses of elements in a compound, which have been determined experimentally, are reported as a percentage**

- **MASS PERCENTAGE COMPOSITION**

$$\%\ \text{by mass of element} = \frac{\text{mass of element present in the sample}}{\text{mass of whole sample}} \times 100$$

Worked Example 3.5 – page 80

A sample of liquid with a mass of 8.657 g was found to contain 5.217 g of carbon, 0.9620 g of hydrogen and 2.478 g of oxygen. What is the percentage composition of the compound?

3.4 Empirical Formulae

- **Chemists can also compare the percentage composition with calculated percentages for POSSIBLE formulas …**

- **Nitrogen and oxygen → N_2O, NO, NO_2, N_2O_3, N_2O_4, N_2O_5**

Worked Example 3.6 – page 81

Are the mass percentages of 25.92% N and 74.09% O consistent with the formula N_2O_5?

$M_N = 14.01\ \mathrm{g\ mol^{-1}}$; $M_O = 16.00\ \mathrm{g\ mol^{-1}}$

3.4 Empirical Formulae

- **Molecular formula - chemical composition of 1 molecule: P_4O_{10}**
- **Empirical formula - simplest whole number ratio: P_2O_5**

Worked Example 3.7 – page 82

A white powder used in paints, enamels and ceramics has the following mass percentage composition: Ba, 69.6%; C, 6.09%; and O, 24.3%. What is its empirical formula?

(M_{Ba} = 137.3 g mol^{-1}; M_C = 12.01 g mol^{-1}; M_O = 16.00 g mol^{-1})

3.4 Empirical Formulae

To determine the empirical formula (page 82)

1. **Assume we are studying 100g of the compound → individual mass percentages determined experimentally become the actual masses**

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3.4 Empirical formulae

2. **Divide the mass of each element by its molar mass**
   - **Calculates the number moles of each element as a ratio**
3. **Divide all numbers in the ratio by the smallest number of moles**
   - **Gives the smallest whole-number ratios of each element**

What is the empirical formula for C_6H_{14}?

A. CH_2
B. C_3H_7
C. C_6H_{14}
D. C_2H_7

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