Chapter 3
Compositions of Substances and Solutions

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Percent Composition

- Percentage of each element in a compound by mass
- Can be determined from

1. the formula of the compound
2. the experimental mass analysis of the compound

- The percentages may not always total to 100% due to rounding

$$\text{Percentage} = \frac{\text{part}}{\text{whole}} \times 100\%$$

Find the mass percent of Cl in $C_2Cl_4F_2$

Practice — Determine the mass percent composition of the following

- $CaCl_2$ (AM Ca = 40.08 amu, Cl = 35.45 amu)

Practice — Benzaldehyde is 79.2% carbon. What mass of benzaldehyde contains 19.8 g of C?

Find the mass of hydrogen in 1.00 gal of water

d_{H2O} = 1.00 g/ml, 3.785 L = 1 gal

How many grams of sodium are in 6.2 g of NaCl? (AM Na = 22.99 amu; Cl = 35.45 amu)

Empirical Formula

- Simplest, whole-number ratio of the atoms of elements in a compound
- NaCl (ratio of Na and Cl = 1:1)
- CH_2O (ratio of C:H:O = 1:2:1)
- Can be determined from elemental analysis (traditional chemical analysis)
  - masses of elements formed when a compound is decompose, or that react together to form a compound
    - combustion analysis
  - percent composition

Finding an Empirical Formula

1. Convert the percentages to grams
   a) assume you start with 100 g of the compound
   b) skip if already grams
2. Convert grams to moles
   a) use molar mass of each element
3. Write a pseudoformula using moles as subscripts
4. Divide all by smallest number of moles
   a) if result is within 0.1 of whole number, round to whole number
5. Multiply all mole ratios by number to make all whole numbers
   a) if ratio ?.5, multiply all by 2; if ratio ?.33 or ?.67, multiply all by 3; if ratio 0.25 or 0.75, multiply all by 4; etc.
   b) skip if already whole numbers

Example (see previous page for procedure)

- Laboratory analysis of aspirin determined the following mass percent composition. Find the empirical formula.

C = 60.00%

H = 4.48%

O = 35.53%

Determine the empirical formula of stannous fluoride, which contains 75.7% Sn (AM: 118.70 amu) and the rest fluorine (AM: 19.00 amu)

Determine the empirical formula of magnetite, which contains 72.4% Fe (AM: 55.85 amu) and the rest oxygen (AM: 16.00 amu)

Molecular Formulas

- Meaningful only molecular compounds
- The molecular formula is a multiple of the empirical formula
- To determine the molecular formula you need to know the empirical formula and the molar mass (molecular weight) of the compound

$$\frac{\text{Molar Mass}_{\text{molecular formula}}}{\text{Molar Mass}_{\text{empirical formula}}} = \text{multiplying factor}, n$$

Find the molecular formula of butanedione

Given: emp. form. = C_2H_3O;
MM = 86.03 g/mol

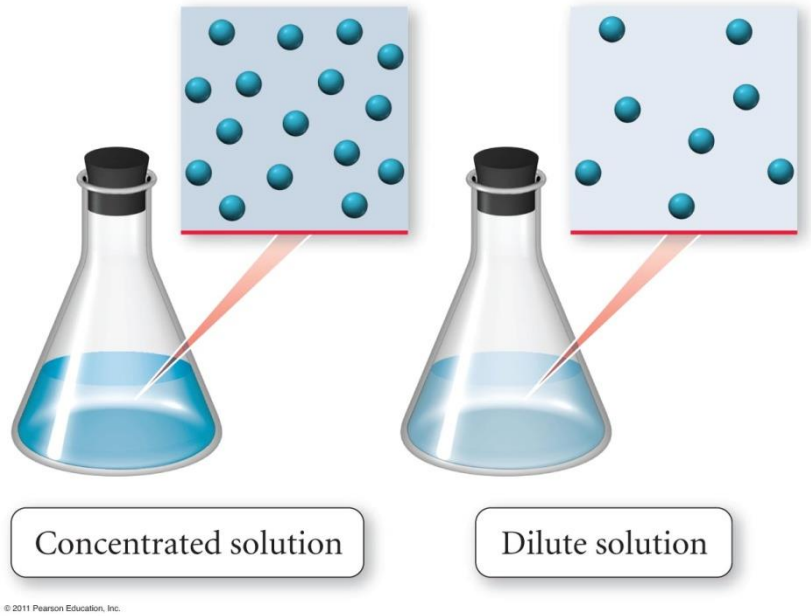
Find: molecular formula

Benzopyrene has a molar mass of 252 g/mol and an empirical formula of C_5H_3. What is its molecular formula? (AM C = 12.01 amu, H=1.0 amu)

Solution:
Solute (Table Salt) + Solvent (Water)

Solution Concentration

- Qualitatively, solutions are often described as dilute or concentrated
- **Dilute solutions** have a small amount of solute compared to solvent
- **Concentrated solutions** have a large amount of solute compared to solvent

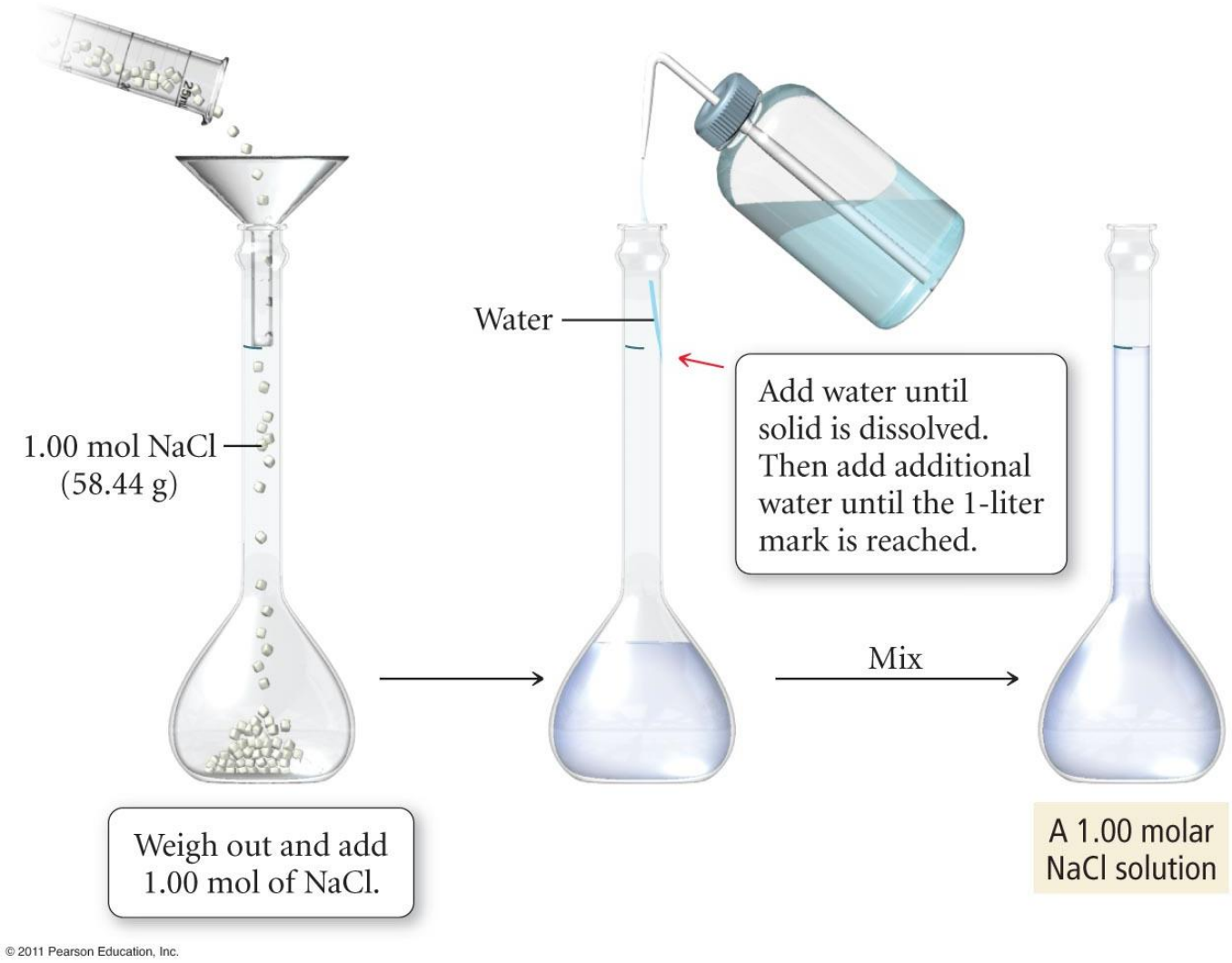


Solution Concentration
Molarity (M)

- Moles of solute per 1 liter of solution
- Used because it describes how many molecules of solute in each liter of solution

$$\text{molarity, M} = \frac{\text{amount of solute (in moles)}}{\text{amount of solution (in L)}}$$

Preparing 1 L of a 1.00 M NaCl Solution



Find the molarity (M) of a solution that has 25.5 g KBr (FM, 119 amu) dissolved in 1.75 L of solution

Practice — What Is the molarity (M) of a solution containing 3.4 g of NH_3 (MM 17.03 amu) in 200.0 mL of solution?

Using Molarity (M) in Calculations

- Molarity shows the relationship between the moles of solute and liters of solution
- If a sugar solution concentration is 2.0 M, then 1 liter of solution contains 2.0 moles of sugar
  - 2 liters = 4.0 moles sugar
  - 0.5 liters = 1.0 mole sugar

$$\frac{2\ \text{mol sugar}}{1\ \text{L solution}}$$

How many liters (L) of 0.125 M NaOH contain 0.255 mol NaOH?

Determine the mass of $CaCl_2$ (FM = 110.98 amu) in 1.75 L of 1.50 M solution

Practice – How would you prepare 250.0 mL of 0.150 M $CaCl_2$ (FM = 110.98 amu)?

Dilution

- To make solutions of lower concentrations from these stock solutions, more solvent is added
  - the amount of solute (mole) doesn't change, just the volume of solution

  moles solute before dilution = moles solute after dilution

- The concentrations and volumes of the stock and new solutions are inversely proportional

$$M_1 \cdot V_1 = M_2 \cdot V_2$$

To what volume should you dilute 0.200 L of 15.0 M NaOH to make 3.00 M NaOH?

What is the concentration of a solution prepared by diluting 45.0 mL of 8.25 M HNO_3 to 135.0 mL?

Concentration: percent (%), parts per million (ppm), and parts per billion (ppb)

- Definitions:

$$\text{mass \%} = \frac{\text{mass of component in solution (g)}}{\text{total mass of solution (g)}} \times 100$$

$$\text{ppm of component} = \frac{\text{mass of component in solution (g)}}{\text{total mass of solution (g)}} \times 10^{6}$$

$$\text{ppb of component} = \frac{\text{mass of component in solution (g)}}{\text{total mass of solution (g)}} \times 10^{9}$$

%, ppm, ppb

(a) A solution made by dissolving 13.5 g of glucose in 0.1kg of water

(b)A 2.5 g sample of ground water containing 5.4 μg of Zn^{2+}

Example

Sea water is typically 3.5% salt and has a density of 1.03 gmL^{-1}. How many grams of salt is required to fill 62.5 L of aquarium?

Homework

To be announced