Section 14.1
Quantitative Expressions of Concentration

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Concentration Units

In this section…

a. Review of solubility
b. Concentration units
    1. molarity
    2. weight percent
        i. ppm
        ii. ppb
    3. molality
    4. mole fraction

Classifications of Solubility

Solubility = how much solute can dissolve in a solution at a given temperature

Saturated solution:

the solute concentration is at the solubility limit at a given temperature

Unsaturated solution:

the solute concentration of a solute is less than the solubility limit at a given temperature

Classifications of Solubility

Supersaturated solution:

the solute concentration exceeds the solubility limit at a given temperature

Miscible mixture: two liquids that mix completely, forming a single phase

Immiscible mixture: two liquids that do not intermix, forming two phases

Concentration units.

The following examples all describe the very same solution.

26.0 g NaCl (0.445 mol NaCl)
100. g H_2O (5.55 mol H_2O)
Total volume = 121 mL

Molarity: M or mol solute/L solution

26.0 g NaCl (0.445 mol NaCl)
100. g H_2O (5.55 mol H_2O)
Total volume = 121 mL

$$\text{molarity} = \frac{\text{amount (mol) solute}}{\text{total volume (L) solution}}$$

$$[\text{NaCl}] = \frac{0.445 \text{ mol NaCl}}{0.121 \text{ L}} = 3.68 \text{ mol/L} = 3.68 \text{ M}$$

Weight percent: %

26.0 g NaCl (0.445 mol NaCl)
100. g H_2O (5.55 mol H_2O)
Total volume = 121 mL

$$\text{weight percent component A} = \frac{\text{quantity (g) component A}}{\text{total mass (g) of solution}} \times 100\%$$

$$\%\ \text{NaCl} = \frac{26.0\ \text{g NaCl}}{26.0\ \text{g NaCl} + 100.0\ \text{g } H_2O} \times 100\% = 20.6\%$$

$$\%\ H_2O = 100.0\% - 20.6\% = 79.4\%$$

Molality: m or mol solute/kg solvent

26.0 g NaCl (0.445 mol NaCl)
100. g H_2O (5.55 mol H_2O)
Total volume = 121 mL

$$\text{molality} = \frac{\text{amount (mol) solute}}{\text{mass (kg) solvent}}$$

$$\text{molality NaCl} = \frac{0.445 \text{ mol NaCl}}{0.100 \text{ kg solvent}} = 4.45 \text{ mol/kg solvent} = 4.45\, m$$

Mole fraction: χ

26.0 g NaCl (0.445 mol NaCl)
100. g H_2O (5.55 mol H_2O)
Total volume = 121 mL

$$\text{mole fraction component A} = \chi_A = \frac{\text{amount (mol) component A}}{\text{total amount (mol) in solution}}$$

$$\text{mole fraction NaCl} = \chi_{NaCl} = \frac{0.445 \text{ mol NaCl}}{0.445 \text{ mol NaCl} + 5.55 \text{ mol } H_2O} = 0.0742$$

Parts per Million and Parts per Billion: Used for dilute solutions

Parts per Million (ppm)

Some useful expressions:

$$1\ ppm = \frac{1\ g\ solute}{10^6 g\ solution}$$

$$1\ ppm = \frac{1\ mg\ solute}{1\ kg\ solution}$$

Parts per Billion (ppm)

Some useful expressions:

$$1\ ppb = \frac{1\ g\ solute}{10^9 g\ solution}$$

$$1\ ppb = \frac{1\ \mu g\ solute}{1\ kg\ solution}$$

22 mL of a 5% solution of NaOCl is added to a washing machine that contains 8.6 gal water (= 32.7 L). What is the concentration NaOCl in ppm and ppb? Assume solution densities = 1 g/mL.

Parts per Million (ppm)

$$1\ ppm = \frac{1\ mg\ solute}{1\ kg\ solution}$$

Parts per Billion (ppm)

$$1\ ppb = \frac{1\ \mu g\ solute}{1\ kg\ solution}$$