CONCENTRATION UNITS

- The concentration of a solution is the amount of solute dissolved in a given amount of solvent.

$$\textbf{Concentration} = \frac{\textbf{amount of solute}}{\textbf{amount of solution}}$$

- Several quantitative expressions of concentration are used in chemistry.

MASSPERCENT

- **Mass percent** (or weight percent) of a solution is the **mass of solute** divided by the **mass of solution**.

$$\textbf{mass \%} = \frac{\textbf{mass of solute}}{\textbf{mass of solution}} \textbf{x100}$$

$$\textbf{mass of solution} = \textbf{mass of solute} + \textbf{mass of solvent}$$

Example:

1. A solution is prepared by dissolving 13.5 g of sugar in 0.100 kg of water. What is the mass % of this solution?

CONCENTRATION UNITS

MOLEFRACTION

- Mole fraction is defined as the moles of solute divided by total moles of solute and solvent.

$$\text{Mole fraction} = \frac{\text{moles of solute}}{\text{moles of solute + moles of solvent}}$$

Example:

2. A solution of hydrochloric acid contains 36% HCl by mass. Calculate the mole fraction of HCl in this solution.

MOLARITY&MOLALITY

- Molarity is defined as the moles of solute divided by liters of solution.

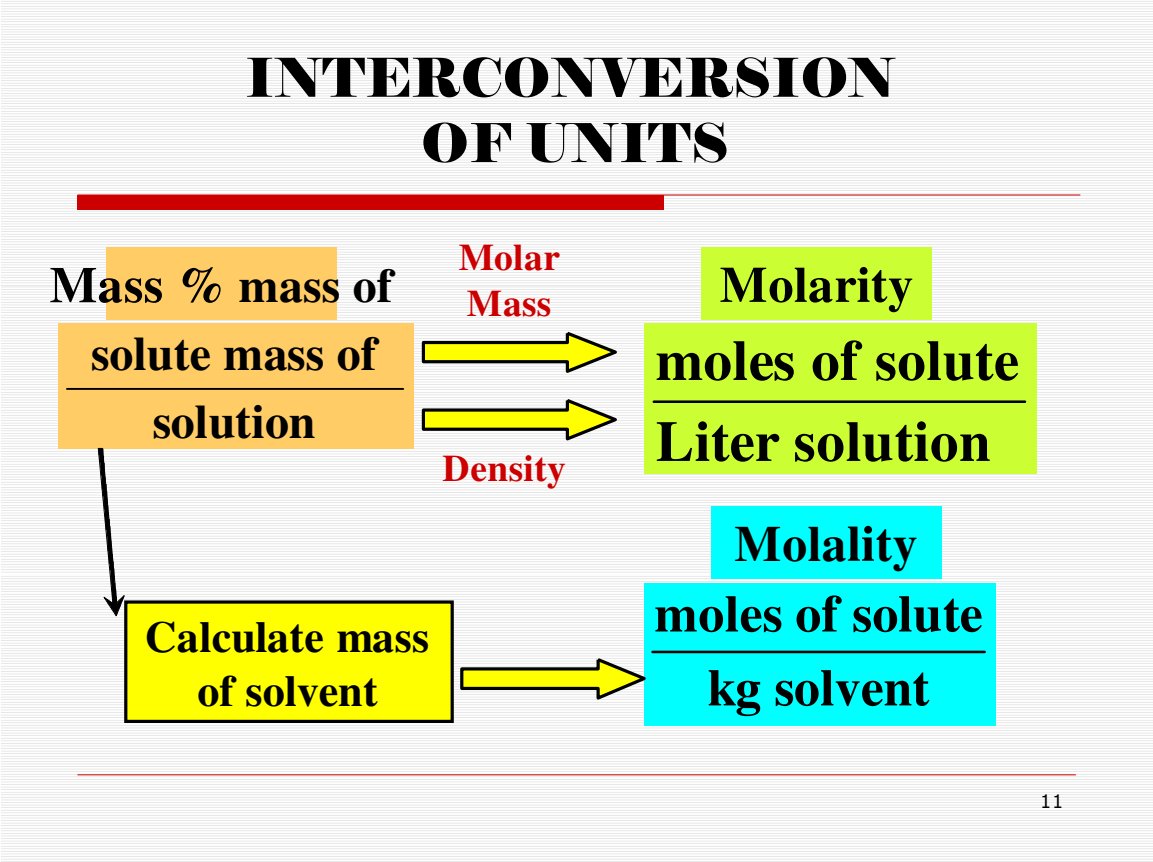
$$\text{Molarity} = \frac{\text{moles of solute}}{\text{Liter of solution}}$$

- Molality is defined as the moles of solute divided by kilograms of solvent.

$$\text{Molality} = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

Examples:

3. A solution containing equal masses of glycerol, $C_3H_8O_3$, and water has a density of 1.10 g/mL. Calculate the molarity and molality of this solution.



INTERCONVERSION OF UNITS

Examples:

4. A solution of H_2O_2 is 30.0% by mass with a density of 1.11 g/mL. Calculate the molarity, molality and mole fraction of this solution.

COLLIGATIVE PROPERTIES

- Physical properties of solutions that depend on the ***concentration***, but not the ***type*** of solute particles are called ***colligative*** properties.

- Examples of such properties are:

  Lowering of vapor pressure
  Lowering of freezing point
  Elevation of boiling point
  Osmotic pressure

VAPOR PRESSURE LOWERING

- The pressure of the vapor above a liquid at a given temperature is defined as vapor pressure.

- A nonvolatile solute lowers the vapor pressure of a volatile liquid, proportional to its concentration.

- This effect is expressed quantitatively as Raoult's law:

$$\mathbf{P_A = X_A P_A^0}$$

P_A = vapor pressure of solution

P_A^0 = vapor pressure of pure solvent

X_A = mole fraction of solvent

Example:

Calculate the vapor pressure of a solution prepared by dissolving 63.0 g of glycerine ($C_3H_8O_3$) in 500. g of w

VAPOR PRESSURE LOWERING

- The lowering of the vapor pressure can be directly calculated by the following equation:

$$\Delta P = X_B P_A^0$$

ΔP = vapor pressure lowering

P_A^0 = vapor pressure of pure solvent

X_B = mole fraction of solute

Example:

What is the vapor pressure lowering of a solution prepared by dissolving 1.20 g of naphthalene ($C_{10}H_8$) in 25.6 g of benzene (C_6H_6)? (P^O = 86.0 torr)

SOLUTIONS WITH 2 VOLATILE COMPONENTS

- Vapor pressure of solutions containing two volatile components (e.g. gasoline) can be determined using Raoult's law.
- Consider a solution containing two volatile components A and B.
- The partial pressure of each component can be determined by using Raoult's law.

$$P_A = X_A P_A^0 \qquad P_B = X_B P_B^0$$

$$P_T = P_A + P_B = X_A P_A^0 + X_B P_B^0$$

Example:

At 63ºC, vapor pressure of water is 175 torr and that of ethanol (C_2H_5OH) is 400. torr. A sol mixing equal masses of water and ethanol. What is the vapor pressure of the solution at this

COMPOSITION OF VAPOR vs. SOLUTION

Calculatemolefractionofeachcomponentinvapor

$$X_A \text{ (in vapor)} = \frac{P_A}{P_T} =$$

$$X_B \text{ (in vapor)} = \frac{P_B}{P_T} =$$

CompositioninSolution

$X_A =$ $X_B =$

CompositioninVapor

$X_A =$ $X_B =$

BOILING POINT ELEVATION

- Addition of a nonvolatile solute to a solvent lowers its vapor pressure and as a result increases its boiling point.
- This boiling point elevation is proportional to the amount of solute in a solution.

$$\Delta T_b = m K_b$$

ΔT_b = boiling point elevation
K_b = boiling point elevation constant
m = molality of solution

FREEZING POINT DEPRESSION

- Addition of a nonvolatile solute to a solvent lowers its freezing point.
- This freezing point depression is proportional to the amount of solute in a solution.

$$\Delta T_f = m K_f$$

ΔT_f = freezing point depression
K_f = freezing point depression constant
m = molality of solution

Example:
A solution of antifreeze contains 25% by mass ethylene glycol ($C_2H_6O_2$) in water. Calculate the boiling point and freezing point of this solution?
(K_b = 0.52 ºC/m and K_f =1.86 ºC/m)

COLLIGATIVE PROPERTIES OF IONIC SOLUTIONS

- When evaluating colligative properties of ionic solutions, the total concentration of the ions must be considered.
- The number of ions produced from each formula unit is designated ***i***.

$NaCl \rightarrow$ ***i* =**

$MgCl_2 \rightarrow$ ***i* =**

- The colligative properties can be calculated with the following modifications:

$$\Delta P = i\, X_B P^0$$
$$\Delta T_b = i\, m\, K_f$$
$$\Delta T_f = i\, m\, K_b$$

Example1:
Calculate the freezing point of 0.010 m solution of aluminum sulfate, $Al_2(SO_4)_3$.

Example2:
Which of the following solutions will have the lowest freezing point?

0.15 m NaCl
0.25 m $C_6H_{12}O_6$
0.10 m $Fe(NO_3)_3$