A. WAYS OF EXPRESSING SOLUTION CONCENTRATION

1. Molarity (M) = $\dfrac{\text{moles of solute}}{\text{volume of solution in litres}}$

2. Mass percent of solute = $\dfrac{\text{mass of solute}}{\text{mass of solution}}$ x 100

3. Molality (m) = $\dfrac{\text{moles of solute}}{\text{kilograms of solvent}}$

4. Mole fraction of a component (X_A) = $\dfrac{\text{moles of substance A}}{\text{total moles of solution}}$

(a) A 1.465 M aqueous solution of fructose ($C_6H_{12}O_6$) has a density of 1.100 g/mL. Calculate the molality of the solution. (*Ans*. 1.752 m)

(b) Calculate the molarity of a 3.50 m aqueous solution of NaCl (d = 1.124 g/mL). (*Ans*. 3.27 M)

B. COLLIGATIVE PROPERTIES: Depression of freezing point & elevation of boiling point.

Colligative properties of solutions are *properties that depend on the concentration of solute particles (molecules or ions) and not on the identity of the solute.*
In this course, only molecular solutes (non-electrolytes) will be considered. Ionic solutes (electrolytes) will be dealt with in CHEM 1210.

When a solute is dissolved in a solvent to make a solution, the boiling point of the solution is **greater** than the boiling point of the solvent (**elevation of the boiling point**) and the freezing point of the solution is **less** than the freezing point of the solvent (**depression of the freezing point**). The change in boiling point or freezing point is proportional to the molality of the solute in the solution.

$$\Delta T_b = K_b m \qquad \Delta T_f = K_f m$$

K_b and K_f are called the boiling-point-elevation constant and the freezing-point-depression constant, respectively, and are constants for the **SOLVENT**. Some values are on the next page.

Solvent	**Boiling pt.**	**Freezing pt.**	K_b**(°C/*m*)**	K_f**(°C/*m*)**
Acetic acid	118.5	16.60	3.08	3.59
Benzene	80.20	5.455	2.61	5.065
Camphor	-	179.5	5.95	40.0
Water	100	0	0.512	1.858

The elevation of the boiling point and the depression of the freezing point for a solution can be calculated using the above equations for known solutes (molar mass known) and for solvents for which K_b *and/or* K_f have been measured. Conversely, measurement of boiling point elevation or freezing point depression can be used to calculate the molar mass of unknown solutes. Since camphor has such a large K_f and melting points can be done on a small scale, the melting point (≡ freezing point) of a solution of an unknown in camphor used to be a popular method of molar mass determination.

(a) Calculate the freezing point of a solution of 15.0 g of urea $[CO(NH_2)_2]$ in 150 g of water. (*Ans.* -3.10°C)

(b) Calculate the freezing point of a solution of 90.0 g of glucose ($C_6H_{12}O_6$) in 300 g of water. (*Ans.* -3.10°C)

(c) Calculate the boiling point of a solution of 20.0 g of naphthalene ($C_{10}H_8$) in 100 g of benzene. (*Ans.* 84.28°C)

(d) Ethylene glycol ($C_2H_6O_2$) is used in anti-freeze. What mass of ethylene glycol must be added to 1.00 gallon (4.55 L) of water to make a solution that freezes at -15°C? (*Ans.* 2.28 kg)

(e) Lauryl alcohol (LA), isolated from coconut oil, has been used in the manufacture of detergents. A solution of 5.00 g of LA in 100 g of benzene has a boiling point of 80.90°C. Calculate the molar mass of LA. (*Ans*. 186 g/mole)

(f) A solution of 55.3 mg of an unknown compound, **A**, in 0.750 g of camphor has a melting point of 168.3°C. Calculate the molar mass of **A**. (*Ans.* 263 g/mole)