Colligative properties are properties that depend only upon the number of solute atoms, ions, or molecules in a solution and not on the nature of those atoms, ions or molecules. Freezing point depressior and boiling point elevation are examples of colligative properties. Raoult discovered that the addition of solute particles causes the boiling point of a solution to be elevated and the freezing point to be depressed. It has been found that 1 mole of nonvolatile, nonionizing solute particles will raise the boiling point of 1.0 kg of water by 0.52 °C, to 100.52°C at 1 atm of pressure. The same concentration will lower the freezing point of 1.0 kg of water by 1.86°C, to -1.86°C. These two numbers apply only to water and are called the molal boiling point and freezing point constants for water. Other solvents have different constants.

PROPERTY	BOILING POINT ELEVATION	FREEZING POINT DEPRESSION
EQUATION	Boiling Point Elevation: A solution wil boil at a higher temperature than the pur solvent. $\Delta T_b = i K_b m$ ΔT_b = change in boiling temp. in (°C) i = a unitless constant (called the van't Hoff factor) associated with the degree of dissociation of the solute in a solvent. K_b = molal boiling point elevation constant (°C/m) **For H_2O: K_b = .52°C/m** m = molality of the solution	Freezing Point Depression: A solution will freeze at a lower temperature than the pure solvent. $\Delta T_f = i K_f m$ ΔT_f = change in freezing temp. in (°C) i = a unitless constant (called the van't Hoff factor)associated with the degree of dissociation of the solute in a solvent. K_f = molal freezing point lowering constant (°C/m) **For H_2O: K_f = 1.86°C/m** m = molality of the solution
GUIDLINES	i = 1 for substances that do not ionize 2 for substances which ionize into two ions like LiCl 3 for substances which ionize into three ions like $CaCl_2$ ....etc. i may have to be calculated if a % of dissociation is given for a solute. If the solvent is not water you must find its K_b.	i = 1 for substances that do not ionize 2 for substances which ionize into two ions like LiCl 3 for substances which ionize into three ions like $CaCl_2$ ....etc. i may have to be calculated if a % of dissociation is given for a solute. If the solvent is not water you must find its K_f.

EXAMPLE #1

If 90.0 g of nonionizing $C_6H_{12}O_6$, are dissolved in 255 g of H_2O, what will be the boiling point of the resulting solution?

First calculate the molality (m) of the solution:

$$m = \frac{92g}{(180 \frac{g}{mole})(0.255 \text{ kg of solvent})} = 2.0 \text{ m}$$

Next apply the boiling point elevation equation:
[i = 1 for a nonionizing solute.]

$\Delta T_b = i K_b m$

$\Delta T_b = (1)(0.52°C/m)(2.0 \text{ m})$

$\Delta T_b = 1.04 °C$

$BP = (\Delta T_b + 100.00 °C)$

$BP = (1.04°C + 100.00 °C) =$ <u>101. 04°C</u>

EXAMPLE #2

If 152 g of sodium sulfate, Na_2SO_4, are dissolved in 875 g of H_2O, what will be the boiling point of the resulting solution? Assume 100% ionization.

First calculate the molality (m) of the solution:

$$m = \frac{152g}{(142 \frac{g}{mole})(0.875 \text{ kg of solvent})} = 1.22 \text{ m}$$

Next apply the freezing point depression equation:

$\Delta T_f = i K_f m$

i = 3 since each unit of Na_2SO_4 yields 3 ions upon dissociation.

$\Delta T_f = (3)(1.86 °C/m)(1.22 m)$
$\Delta T_f = 6.8°C$

$FP = 0.0°C - \Delta T_f$
$FP = 0.0°C - 6.8°C$
$\underline{FP = -6.8°C}$

EXAMPLE #3

Determine the molality of a water solution if the boiling temperature is 104.42°C.

First solve the boiling point elevation equation for molality '"m".

$\Delta T_b = i K_b m$

$$m = \frac{\Delta T_b}{i K_b}$$

ΔT_b = 104.4°C - 100°C = 4.4 °C.
i = 1 (we can assume i is (1) for a problem of this type
K_b = 0.52 °C/m

$$m = \frac{4.4°C}{(1)(0.52 \frac{°C}{m})} = 8.46 \text{ m}$$

Example #4

A solution of a nonelectrolyte contains 30 g of solute dissolved in 250 g of water. The boiling point of the water is observed to be 101.04°C. What is the GMM of this substance?

the molality of the solution can be calculated by using:
$m = (\Delta T_b)/(i)(K_b) = (1.04°C)/(1)(0.52°C/m) = 2.0$ m

Then use this equation grams = (m)(GMM)(kg of solvent)

(Solve for GMM) GMM = (grams)/(m)(kg of solvent) = (30 g)/(2 moles/kg)(0.250 kg) = <u>60g/mole</u>

Practice Problems:

A. Calculate the molality, freezing point, and boiling point for each of the following water solutions of nonionizing solutes:

1. 144 g of $C_6H_{12}O_6$ dissolved in 1000 g of H_2O

2. 48 g of CH_3OH dissolved in 200 g of H_2O

3. 184 g of C_2H_5OH dissolved in 400 g of H_2O

4. 600 g of C_3H_7OH dissolved in 600 g of H_2O

5. 100 g of of $C_2H_6O_2$ dissolved in 200 g of H_2O

B. Calculate the molality of a water solution if the freezing point is:

6. -9.3°C

7. -27.9°C

8. -7.44°C

C. Calculate the molality of a water solution if the boiling point is:

9. 103.12°C

10. 108. 32°C

D. Solve the following Problems

11. What is the boiling point of a solution made by dissolving 31 g of NaCl in 559 g of water? (Assume 100% ionization of NaCl.)

12. Calculate the freezing point of an a nonionizing antifreeze solution containing 388g ethylene glycol, $C_2H_6O_2$, and 409 g of water.

13. Calculate the boiling point of an ionic solution containing 29.7 g Na_2SO_4 and 84.4 g water. (Assume 100% ionization.)

14. What is the molecular mass of a substance if 22.5 g dissolved in 250 g of water produces a solution whose freezing point is -0.930°C?

15 If 4.18 g of a nonionic solute is dissolved in 36.30 g of benzene, C_6H_6 , the freezing point is 2.70 °C. Find the molar mass of this solute. The freezing point of benzene is 5.53 °C and the K_f is 5.12 °C /m.