Name: SOLUTIONS Chem B Unit 9, Day 7-9: Colligative Properties

Hour: ______ Date: ___________

Molality: The concentration calculation of champions (or at least of colligative properties)! (Day 7: Ch. 16.4)

Today, we are going to complete the Solution Concentration *chart that we have been building over the past few days. Use the chart to answer the following questions:*

1) To make a 0.06 m KI solution,
   a. How many moles of KI would you need to add to 500 g H_2O?

   $0.06\ m = \frac{x \text{ mol KI}}{0.5 \text{ kg } H_2O}$ $(0.06 \frac{\text{mol}}{\text{kg}})(0.5 \text{ kg } H_2O) = $ **0.03 mol KI**

   b. How many grams of KI is this?

   $0.03 \text{ mol KI} \times \frac{165.998 \text{ g KI}}{1 \text{ mol KI}} = $ **4.98 g KI**

2) What's the difference between a 1 M solution and a 1 *m* solution of KNO_3?
   - 1 M solution indicates that we have 1 mol KNO_3 in 1 L of solution.
   - 1 m solution indicates that we have 1 mol KNO_3 in 1 kg of water.

3) What is the molality of the NaF solution if 0.50 moles of sodium fluoride is added to 750 g of water?

   Equation: $m = \frac{\text{mol}}{\text{kg}}$ Answer: 0.65 m NaF

   $m = \frac{0.50 \text{ mol NaF}}{0.75 \text{ kg } H_2O} = 0.67\ m$ NaF solution

4) Calculate the molality of a solution prepared by dissolving 10.0 g NaCl in 600g of water.

   Equation: $m = \frac{\text{mol NaCl}}{\text{kg } H_2O}$ Answer: 0.287 m NaCl

   1) $g_{NaCl} \rightarrow mol_{NaCl}$ 2) $m = \text{mol/kg}$

   $\frac{10.0 \text{ g NaCl} \times \frac{1 \text{ mol NaCl}}{58 \text{ g NaCl}}}{0.6 \text{ kg } H_2O} = 0.287 \text{ mol/kg}$

   2) $g_{H_2O} \rightarrow kg_{H_2O}$ $600 \text{ g} \times \frac{1 \text{ kg}}{1000 \text{ g}}$

Conceptual problems (Day 7: Ch. 16.3)

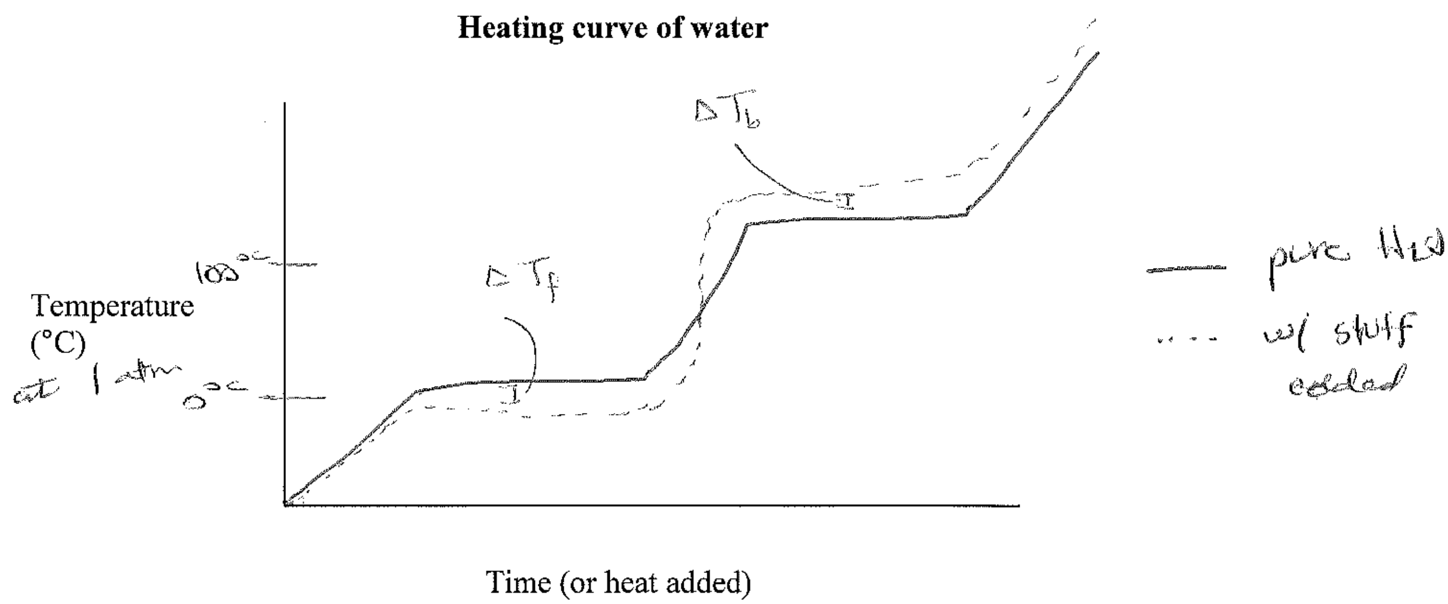
Colligative properties *are properties that depend only upon*

the # particles *in a solution and not on the*

the specific nature of those particles (identity).

- *Freezing point depression and boiling point elevation are examples of colligative properties.*
- *Examples in daily life:* *1.* Making ice cream *2.* Keeping roads safe in winter *3.* Making water boil hotter.
- *Raoult discovered that the addition of solute particles causes the boiling point of a solution to be raised and the freezing point to be lowered.*

Heating Curve of a MIXTURE:

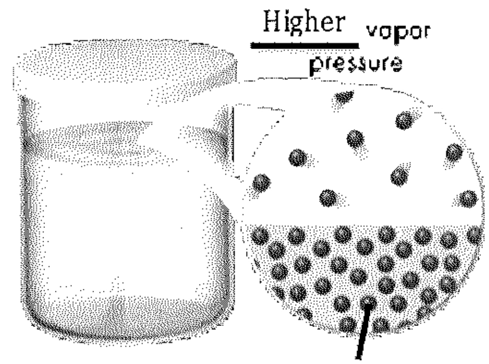


→ Mixtures of water has a lower FP & a higher BP due to Δ Vapor pressure.

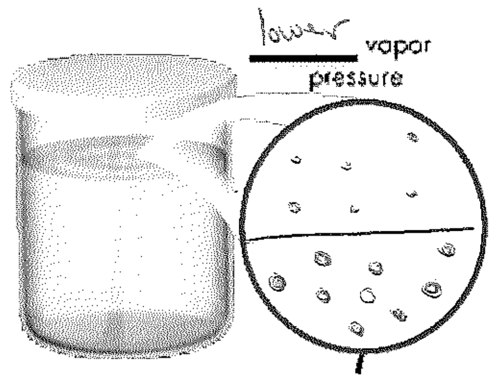
→ Caused by ↑ interactions of H_2O w/ particles. The H_2O molecules won't have as much available KE to escape from solution.

Colligative properties depend on the **number** of particles, ions or molecules of solute present in solution.

Factor 1: Concentration of solute

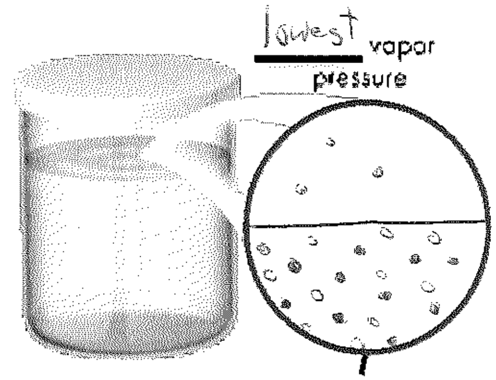


Pure water



1 m sugar solution

o - sugar

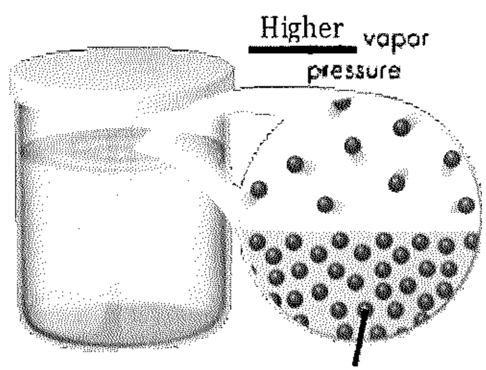


10 m sugar solution

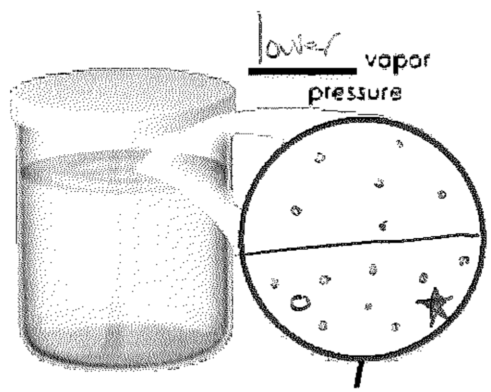
o - sugar

↑ # particles ↓ VP

Factor 2: Solute dissociation



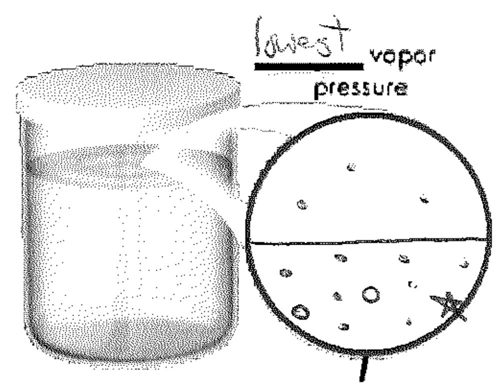
Pure water



1 m NaCl solution

o - Na^+

★ - Cl^-



1 m Na_2SO_4 solution

o - Na^+

★ - SO_4^{2-}

↑ # particles (e.g. # ions) ↓ VP

Colligative properties: The ion factor (Day 8)

5) Would a dilute or a concentrated sodium fluoride solution have a higher boiling point? Explain.

i.e. What will cause VP be more affected? More stuff!

a concentrated solution of NaF will have a higher BP because more ions will be present & will interact w/ water molecules which causes KE of water molecules to ↓ ∴ ↓VP ∴ ↑BP

6) Identify: What is the ion factor (i) for the following compounds:

a. Na_2SO_4: 3 — $2\ Na^+$ $1\ SO_4^{2-}$

b. Glucose: 1 — doesn't break up at all

c. KNO_3: 2 — K^+ NO_3^-

d. $Al(NO_3)_3$: 4 — Al^{3+} $3\ NO_3^-$

7) Compare: An equal number of moles of KI and MgI_2 are dissolved in equal volumes of water. Identify which solution has a higher:

e. Vapor pressure: KI

f. Boiling point: MgI_2

g. Freezing point: KI

KI : 2 ions
MgI_2 : 3 ions → ↓VP, ↑BP, ↓BP

8) Apply: When the water inside a living cell freezes, the ice crystals damage the cell. The wood frog is unique creates that can survive being frozen. In extremely cold conditions, the frog's liver produces large amounts of glucose ($C_6H_{12}O_6$), which becomes concentrated in the frog's cells. How does the glucose help prevent ice from forming in the frog's cells?

Adding glucose to blood stream will lower freezing point of water in cells, such that the conditions must be lower than 0°C to freeze the ~~frog~~ frog's blood.

Summary: ↑[glucose] leads to ↓FP ∴ frog lives :)

Colligative properties: Calculations! (Day 9)

Bellwork:

We're going to be work through a couple of problems together as a class and then breaking up into small groups to complete the packet.

Whole-class problems:

9) Boiling-point elevation problem: ΔT_b m

What is the boiling point elevation of water when you mix 0.3 moles KI into 0.500 kg water? i

$\Delta T_b = K_b \cdot m \cdot i$

$m = \frac{0.3 \text{ mol KI}}{0.5 \text{ kg } H_2O} = 0.6 \text{ m KI}$

$i = 2 \quad (K^+ + I^-)$

$K_b = 0.515\ °C/m$

$\Delta T_b = (0.515\ °C/m)(0.6\ m\ KI)(2)$

$= 0.618\ °C$ $\quad \therefore$ $\boxed{\Delta T_b = 0.6\ °C}$

(1 sig fig)

Small-group problems:

10) Freezing-point depression problem:

What is the freezing point of water when you mix 10 g KI into 0.500 kg water?

a. Determine ion factor of the solution:

i of KI is i=2

b. Determine the molality of this solution:

$$m = \frac{10\text{ g KI} \mid 1\text{ mol KI}}{\mid 166\text{ g KI} \mid 0.5\text{ kg } H_2O} = 0.12\ m\text{ KI}$$

c. Determine freezing-point depression of this solution.

$$\Delta T_f = K_f \cdot i \cdot m$$

$$= (1.86\ °C/m)(2)(0.12\ m) = 0.4\ °C$$

$$\therefore \Delta T_f = 0.4\ °C$$

Individual problems:

After working through problems 2 as a small group, you can choose how to work through the remaining problems. These can be completed alone or with a partner in your small group. If you feel confident with a section of problems and feel that you have had enough practice with this problem type, get Ms P or Mr Erickson's signature on the bottom of that section. You will not be held accountable for any unanswered questions in the section.

Change in phase change temperature

11) What is the *change* in water's freezing point if the solution that contains 5.3 *m* NaCl?

$$\Delta T_f = K_f \cdot i \cdot m$$

$K_f = 1.86\ °C/m$

$i = 2$

$m = 5.3\ m$

$$\Delta T_f = (1.86\ °C/m)(2)(5.3\ m) = 19.7\ °C$$

12) What is the *change* in boiling point of a solution that contains 1.25 mol $CaCl_2$ in 1400 g of water?

$K_b = 0.515\ °C/m$

$i = 3$

$$m = \frac{1.25\text{ mol } CaCl_2}{1.4\text{ kg } H_2O} = 0.89\ m$$

$$\Delta T_b = K_b \cdot i \cdot m$$

$$= (0.515\ °C/m)(3)(0.89\ m)$$

$$\Delta T_b = 1.4\ °C$$

13) A 0.3 *m* sugar solution is heated over a Bunsen burner and it starts to boil. What temperature do you expect the thermometer to read when placed in the boiling solution? (Assume that the thermometer can read to the tenths place).

$T_b = 100°C + \Delta T_b$

$K_b = 0.515°C$

$i = 1$

$m = 0.3\ m$

where $\Delta T_b = K_b \cdot i \cdot m$

$= (0.515°C/m)(1)(0.3\ m) = 0.15°C$

$T_b = 100°C + 0.15°C = 100.15°C$

Determining molality from temperature change

14) Calculate the molality of a ~~benzene~~ water solution if the boiling point is: (Assume $i = 1$ in both cases)

$K_b = 0.515\ °C/m$ ~~for benzene~~

a. 103.12 °C.

$\Delta T_b = 103.12 - 100 = 3.12°C = K_b \cdot i \cdot m$

$m = \frac{\Delta T_b}{K_b \cdot i} = \frac{3.12°C}{(0.515°C/m)(1)} = 6.06\ m$

b. 108. 32°C.

$\Delta T_b = 8.32°C = K_b \cdot i \cdot m$

$m = \frac{\Delta T_b}{K_b \cdot i} = \frac{8.32°C}{(0.515°C/m)(1)} = 16\ m$

15) Calculate the molality of a water solution if the freezing point is: (Assume $i = 1$ in both cases)

a. -9.3°C.

$\Delta T_f = K_f \cdot m \cdot i = 0 - (-9.3°C) = 9.3°C$

$m = \frac{\Delta T_f}{K_f \cdot i} = \frac{9.3°C}{(1.83°C/m)(1)} = 5\ m$

b. -27.9°C

$\Delta T_f = K_f \cdot m \cdot i = 0 - (-27.9°C)$

$m = \frac{\Delta T_f}{K_f \cdot i} = \frac{27.9°C}{(1.86°C/m)(1)} = 15\ m$

Determining molality and change in temperature

16) What is freezing point depression (i.e. the change in temperature) of a solution containing 132 g $C_{12}H_{22}O_{11}$ and 250 g of H_2O? $\Delta T_f = K_f \cdot i \cdot m$

$K_f = 1.86°C/m$

$i = 1$

$m = \frac{132\,g}{} \cdot \frac{1\,mol\,C_{12}H_{22}O_{11}}{342.3\,g} \cdot \frac{}{0.25\,kg\,H_2O} = 1.54\,m$

$\Delta T_f = (1.86°C/m)(1)(1.54\,m) = \boxed{2.86°C = \Delta T_f}$

17) Calculate the boiling point of an ionic solution containing 29.7 g Na_2SO_4 and 84.4 g water (Assume 100% ionization.) (T_b; $i = 3$)

$T_b = 100°C + \Delta T_b$ where $\Delta T_b = K_b \cdot i \cdot m$

$K_b = 0.515°C/m$

$i = 3$

$m = \frac{29.7\,g\,Na_2SO_4}{} \cdot \frac{1\,mol\,Na_2SO_4}{124\,g\,Na_2SO_4} \cdot \frac{}{0.0844\,kg\,H_2O} = 2.84\,m$

$\Delta T_b = (0.515°C/m)(3)(2.84\,m) = 4.38°C$ $\therefore \boxed{T_b = 104.4°C}$

18) Calculate the freezing point depression of a benzene solution containing 400 g of benzene and 200 g of a molecular compound (C_3H_6O). ($K_b = ?$)

$\Delta T_b = K_b \cdot i \cdot m$

$K_b = 2.65°C/m$

$i = 1$

$m = \frac{200\,g}{} \cdot \frac{1\,mol\,C_3H_6O}{58.1\,g} \cdot \frac{}{0.4\,kg\,benzene} = 8.61\,m$

$\Delta T_b = (2.65°C/m)(1)(8.61\,m) = \boxed{22.8°C}$

19) What is the freezing point of an aqueous solution of 10.0 g of glucose ($C_6H_{12}O_6$) in 50.0 grams of water? (T_f; $i = 1$)

$K_f = 1.86°C/m$

$i = 1$

$m = \frac{10\,g\,glucose}{} \cdot \frac{1\,mol\,glucose}{180.2\,g\,glucose} \cdot \frac{}{0.05\,kg\,H_2O} = 1.11\,m$

$T_f = 0 - (\Delta T_f)$ where $\Delta T_f = (1.86°C/m)(1)(1.11\,m) = 2.06$

$\boxed{T_f = 0 - 2.06°C = -2.06°C}$

Exit ticket

Challenge Problems: $i = 1$ (molecules don't ionize)

20) 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?

T_f

$$\Delta T_f = 0.93\,°C = K_f \cdot i \cdot m = (1.86\,°C/m)(1)(m)$$

$$\therefore m = \frac{0.93\,°C}{(1.86\,°C/m)(1)} = \frac{0.5 \text{ mol}}{\text{kg}} \times 0.25 \text{ kg} = 0.125 \text{ mol}$$

∴ If 0.125 mol = 22.5 g, the molecular mass is

$$\boxed{MM = \frac{22.5\text{ g}}{0.125 \text{ mol}} = 180 \text{ g/mol}}$$ ← perhaps glucose?

21) The solubility of methane, the major component of natural gas, in water at 20.0 °C and 1.00 atm pressure is 0.026 g/L. If the temperature remains constant, what will the solubility of the gas at 0.6 atm?

$$\frac{Sol_a}{P_a} = \frac{Sol_b}{P_b}$$

$$\frac{(0.026 \text{ g/L})}{(1 \text{ atm})} = \frac{x}{(0.6 \text{ atm})}$$

$$Sol_b = \frac{(Sol_a)(P_b)}{P_a} = \frac{(0.026 \text{ g/L})(0.6 \text{ atm})}{1 \text{ atm}}$$

$$\boxed{Sol_b = 0.16 \text{ g/L}}$$