

CH302 Worksheet 2 Colligative Properties

All of this is intended to be done without the aid of a calculator. All of the calculations are designed such that approximating should be straight-forward and produce a correct result.

1. Based on the physical constants involved, which colligative property has the greatest magnitude for a solution of a given concentration? Which can't be compared in this way? Why?

Osmotic pressure - except at extremely low temperatures - the RT term is going to be much larger than the value of k_b or k_f . It is difficult to compare Raoult's Law in these terms because it uses no physical constants.

2. Which colligative properties have a linear concentration dependence? Write their equations.

All colligative properties have a linear concentration dependence.

Osmotic pressure ($\Pi = i \cdot M \cdot R \cdot T$)

Boiling point elevation ($\Delta T_b = i \cdot m \cdot K_b$)

Freezing point depression ($\Delta T_f = -i \cdot m \cdot K_f$)

Vapor pressure lowering ($P = P^\circ \cdot x$)

3. Rank the following aqueous solutions in terms of increasing boiling point: 3 *m* sugar, 2 *m* NaCl, 0.5 *m* Mg(OH)₂, 5 *m* AlN, 1 *m* urea.

5 *m* AlN < 1 *m* urea < 0.5 *m* Mg(OH)₂ < 3 *m* sugar < 2 *m* NaCl

4. Assuming a cell wall can withstand an osmotic pressure of 1 atmosphere and the concentration of Na⁺ in a cell is 50 mM, approximate the [Na⁺] outside the cell that would cause lysis.

The product of 0.0821 L·atm·mole⁻¹·K⁻¹ and 298 K is roughly 25 L·atm·mol⁻¹ (or atm·M⁻¹).

1 atmosphere of pressure would thus be produced by roughly 40 mM Na⁺.

Therefore an exterior concentration of approximately 10 mM Na⁺ (or less) would be required.

5. If you dissolved 28 grams of NaCl in 90 grams of pure H₂O hot enough to have a vapor pressure of 30 torr, what will the new vapor pressure be?

The molecular weight of NaCl is roughly 58 g·mol⁻¹, so we have about 0.5 mol of NaCl.

The molecular weight of H₂O is roughly 18 g·mol⁻¹, so we have about 5 mol of water.

The mol fraction of water is therefore 5/6, times a vapor pressure 30 torr for pure water, is roughly 25 torr for the new solution.

6. Assuming standard conditions and a $K_f = 0.2 \text{ K} \cdot m^{-1}$ and a $K_b = 0.5 \text{ K} \cdot m^{-1}$ for water, what would be the freezing point of a solution that boiled at 375.5 K? Express your answer in both K and °C.

The normal boiling point of water is 373 K, so we have a $\Delta T_b = 2.5 \text{ K}$, which equates to an effective molality of $m = 5$, resulting in a $\Delta T_f = -1 \text{ K}$, so our solution will freeze at 272 K, or -1 °C.

7. Based on the question above and assuming 1 kg of water, how many moles of NaCl would be needed to produce this effect? What about sugar?

Accounting for the van't Hoff coefficient, 2.5 moles of NaCl would produce a 5 *m* solution.

It would take 5 moles of sugar to produce the same effect.

8. Based on your understanding of boiling point elevation, why **doesn't** salting water help food to cook faster?

The effects involved are very small. Given the magnitude of the boiling point elevation constant as well as the amount of salt required to achieve even a 1 *m* solution, the change in boiling point resulting from salting food is too small to substantially effect cooking times.

9. Vapor pressure is often described as a "surface phenomenon." Define this term in your own words to the best of your ability.

A surface phenomenon is simply a process (such as evaporation/condensation) that takes place at a

surface where two phases meet. This makes sense, as the only place a water molecule could switch between two phases is the place where they meet, just as the only place a person can go from inside to outside is at a doorway that connects the two.

10. Raoult's can be used to calculate the decrease in vapor pressure when a non-volatile substance (like salt) is dissolved in a volatile substance (like water). Explain this phenomenon.

Since evaporation is a surface phenomenon, by adding something like salt to water, part of the surface area is now occupied by salt ions instead of water molecule, diminishing the probability that a water molecule will escape the surface.