Colligative Properties of Solutions

How do you get from this…

…to this?

Add an ionic compound!

Pure Solvent vs Solutions

The properties of a pure solvent are different than the properties of a solution made from that solvent.

Characteristic properties such as boiling point and freezing point are changed when a solute is put in a solvent

Colligative Properties

- Properties that depend only on the number of solute particles and not on their identity.

- Since the number of particles per water molecule determines the change in properties of a solution, we need a new concentration term that gives us this relationship

molality

- Molality = moles solute/ kg solvent
- Symbolized by lower case “m”
- Remember: with molarity, we don’t know exactly how much solvent we have

- Molality is based on kg solvent which may be converted to moles or grams and therefore # of particles

Molality con't

- Therefore, if we have a 1m $C_{12}H_{22}O_{11}$ solution in water, that means we have 1 mole $C_{12}H_{22}O_{11}$ in 1 kg of water.

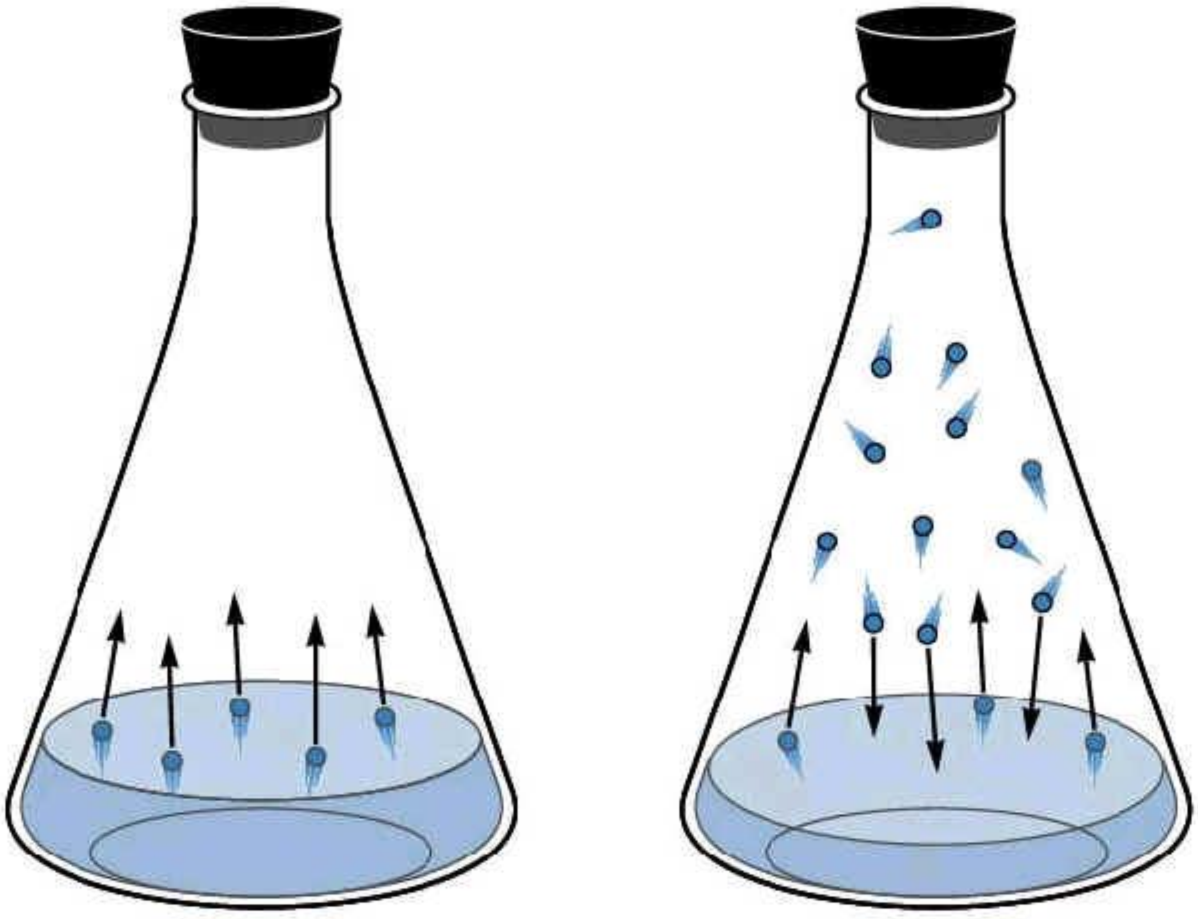
Or

6.02×10^{23} molecules in 3.34×10^{25} molecules of water

Some Colligative Properties are:

- Vapor pressure lowering
- Boiling point elevation
- Freezing Point depression

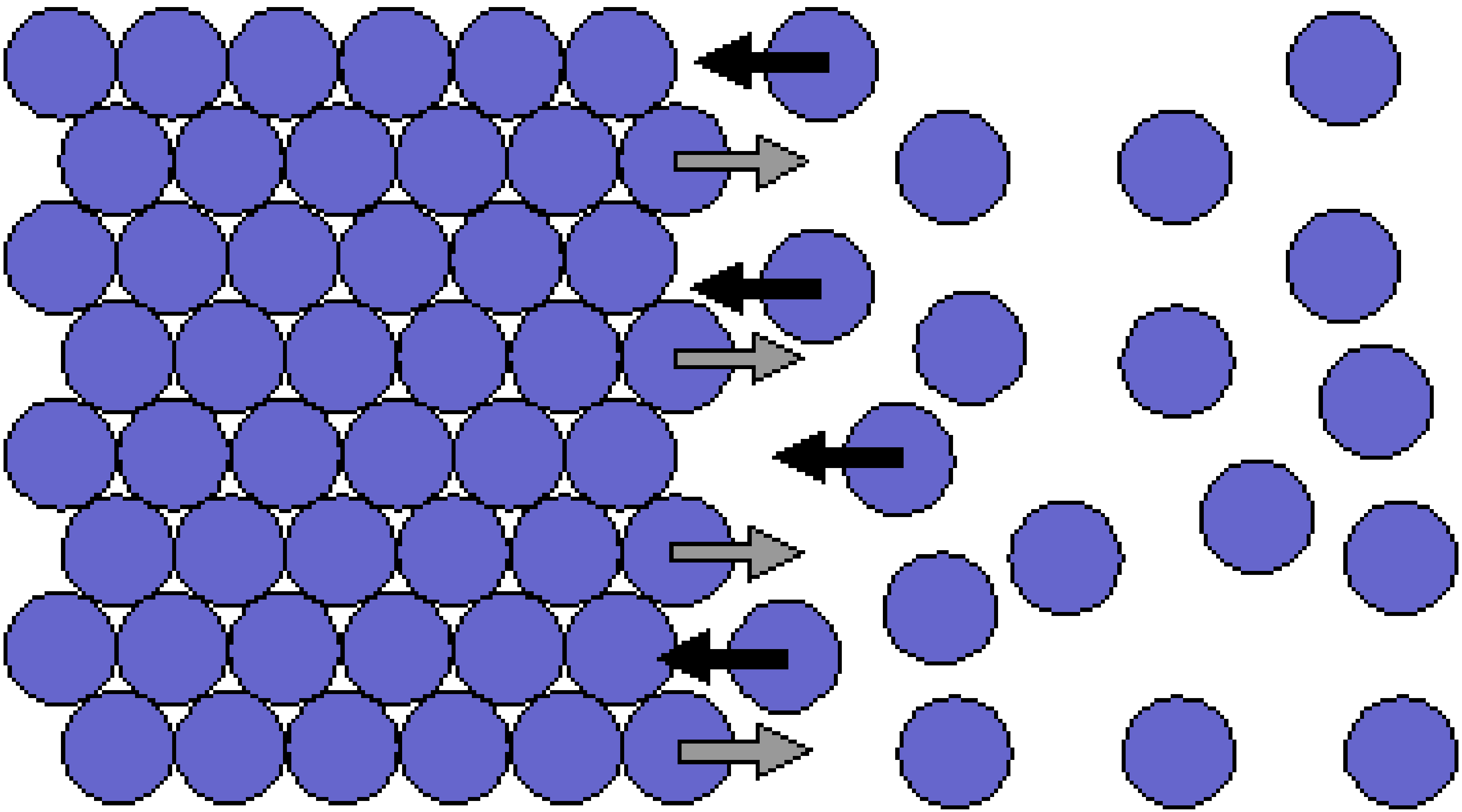
Vapor Pressure



Vapor Pressure Lowering

- Where does vaporization take place?
- The particles of solute are surrounded by and attracted to particles of solvent.
- There are fewer solvent particles at the surface of a solution
- Vapor pressure is less.

Freezing Point Depression



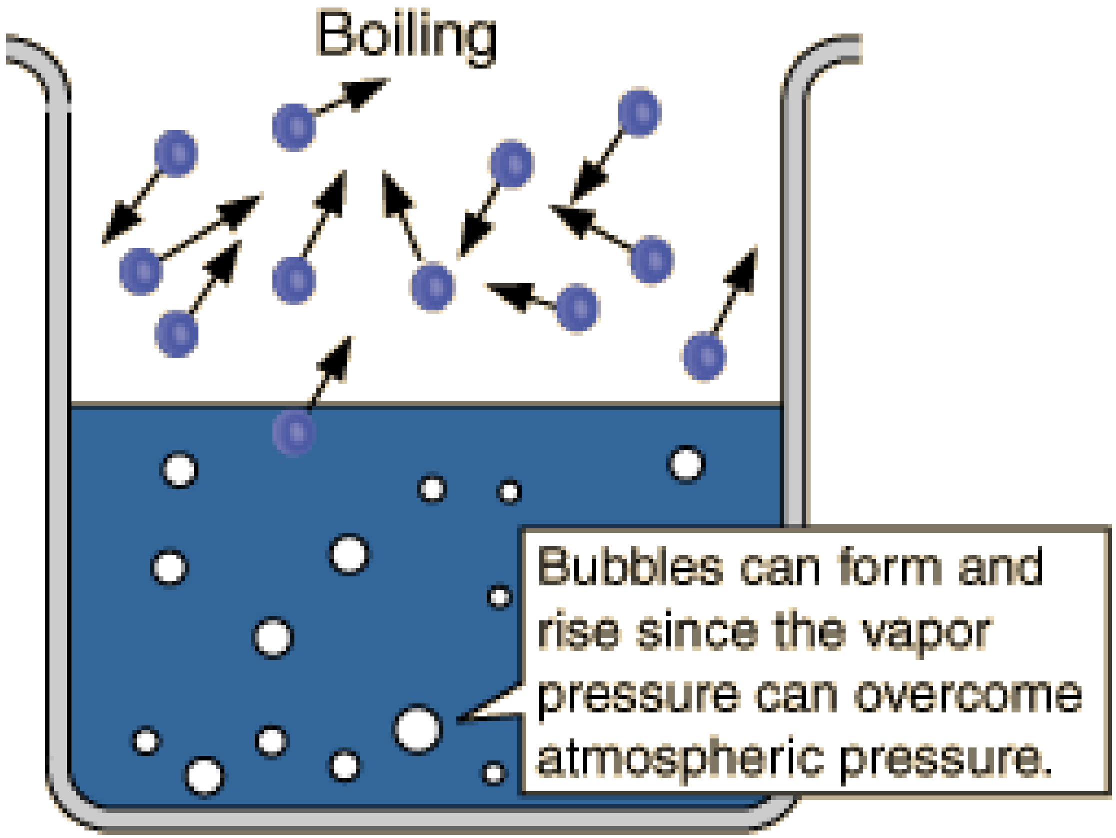
Effect of solutes on freezing

- What has to happen for molecules of a liquid to become solid?
- How would solute particles interfere with this process?
- Freezing point of a solution is always lower than that of the pure solvent

Example

- Salt is added to melt ice by reducing the freezing point of water.

Boiling Point Elevation



What has to happen for boiling to occur?

- How would solute particles interfere with this process?

- Boiling point of a solution is always higher than that of a pure solvent.
- Going back to vapor pressure…if vapor pressure is lower in a solution than in the pure solvent, how would that affect boiling point?

Example

- Addition of ethylene glycol $C_2H_6O_2$ (antifreeze) to car radiators.

Ionic vs Molecular Solutes

- Ionic solutes may produce two or more ion particles in solution thus increasing the number of particles in the solution.
- They affect the colligative properties proportionately more than molecular solutes.
- The effect is proportional to the **number of particles of the solute in the solution.**

How many particles do each of the following give upon solvation?

- NaCl
- $CaCl_2$
- Glucose

Freezing Point Depression and Boiling Point Elevation

Boiling Point Elevation

- $\Delta T_b = mk_{\mathbf{b}}$ (for water k_b=0.512 $^oC/m$)

- Freezing Point Depression
- $\Delta T_f = mk_f$ (for water k_f=1.86 $^oC/m$)
- **Note**: **m is the molality of the particles**, so if the solute is ionic, multiply by the #of particles it dissociates to.

What does this mean??

- If you have a 1 molal solution, the freezing point of a water solution will lower by $1.86^{o}C$.

- If you have a 2 molal solution, the freezing point will lower by $2(1.86^{o}C)$.

- Kf (and Kb) just give you the relationship between molality and change in freezing point/boiling point

Practice

- Calculate the molality of a solution made by mixing 25.0g of sucrose (MW = 342g/mol) in 200.ml H_2O
  - 25.0 g x 1 mol/342g = .0731moles
  - 200. ml H_2O x 1g/ml x 1kg/1000g = .200kg
  - .0731 moles/.200kg = .365 mol/kg = .365m

Example 1:

- Find the new freezing point of .365m sucrose in water.
  - $\Delta T_{=}$ 1.86^{o}C/m x .365m = .679^{o}C
  - Careful!! This is the CHANGE in freezing point. You still have to determine the freezing point itself.
  - For water that is easy - normal freezing point is 0^{o}C, so just subtract ΔT from this
  - O - .679 = -.679^{o}C

Example 2:

- Find the new boiling point of .365m sucrose in water.

- $\Delta T = .512^{o}C/m \times m$

  $= .512^{o}C/m \times .365m = .187^{o}C$

Again..this is just boiling point change:

$100^{o}C + .187 = 100.187^{o}C$

Which is more effective for lowering the freezing point of water?

- NaCl or $CaCl_2$

- If we look at the previous problem, we can see that the sucrose solution had a molality of .365. But a sucrose molecule does not ionize in solution

Answers

- NaCl and $CaCl_2$ both do
- If we had a 0.365m solution of NaCl, we would have 2(0.365m) solution of ions.