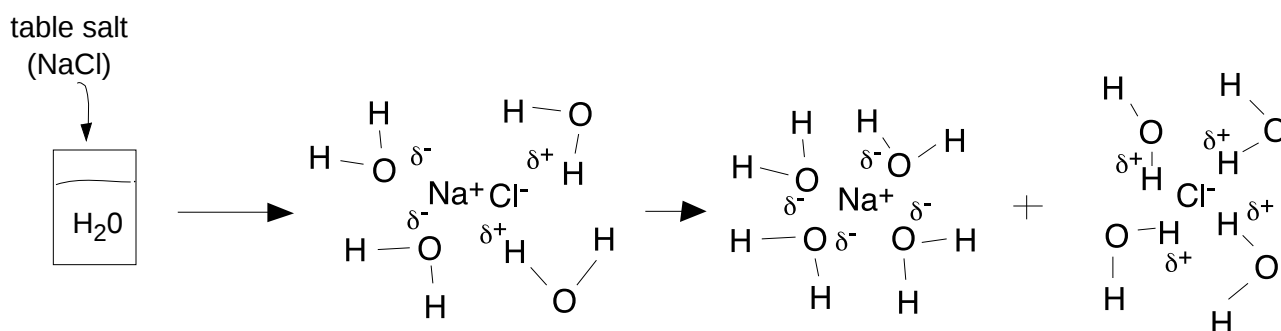


Solutions and the process of solvation

When you put a solid (like table salt, NaCl) into a liquid (like H₂O), the solid (solute) gets surrounded by the liquid (solvent) molecules. If the interaction between solute and solvent molecules is strong enough the solvent molecules will pull apart the solid (solute) and surround the individual ions or molecules of the solute. That's the process of solvation. Here, take a look:



I only put in the polarity on the water molecules that were directly interacting with the solute. The deltas just mean a "little of," so δ⁺ means a little plus charge and δ⁻ means a little minus charge.

H₂O is such a good solvent (it's called the universal solvent) because of its polar character (it has lots of ways to attract positively and negatively charged species)

In a simplistic way, a solution is saturated when all of the spots in the solvent into which solute molecules can fit are filled. Addition of more solute would cause precipitation. In an unsaturated solution you still have room to solvate more solute molecules. In a supersaturated solution more solute molecules are solvated than equilibrium specifies. (This is an inherently unstable situation.)

Electrolytes are solutions in which ionic molecules (like NaCl) break up into cations and anions in the solution. The ions are mobile and therefore these electrolyte solutions can conduct electricity.

Nonelectrolytes are solutions in which neutral molecules are dissolved (like sugar in water). These guys don't conduct electricity.

Electrolytes and nonelectrolytes have different properties from those of the pure solvent. Colligative properties are properties of the solution. They depend only upon how much solute has been dissolved into the solvent. The colligative property stuff you have to know deals with boiling point (you put salt into water to make it boil at a higher temperature), the freezing point (we salt roads in the winter to reduce the freezing point of water as well as subsidize the automobile industry), and the osmotic pressure of a solution (osmotic pressure is weird, it basically is a pressure exerted at an interface between two liquid phases that have different solute concentrations; the less concentrated side will try to force solution through the barrier so that the more concentrated side will become diluted. Know those little colligative properties equations and how to use molality for concentration. Remember that if the solute breaks up into ions, then you have to take that into account when calculating molality.

For both electrolytes and nonelectrolytes, the addition of the solute molecules changes some properties of the liquid solvent. Colligative means that these properties depend only upon the amount of the solute dissolved in the solvent and not what the particular solute is.

Different Ways of Expressing Concentration for Solutions

Mass % Solute	ppm	ppb
$\frac{\text{mass solute}}{\text{total mass solution}}$	$\longrightarrow \text{mass \%} \times 10^4$	$\longrightarrow \text{mass \%} \times 10^7$
Remember that when you add something to a solution you change the total mass of the solution. You have to keep track of what you add, not just the amount of solvent that you start with.		

Mole fraction, X_A	Molality, m
$X_A = \frac{\text{moles A}}{\text{total moles solution}}$	$m = \frac{\text{moles solute}}{\text{kilograms solvent}}$ - Here it doesn't matter how much solute you add, it's always based upon the number of kilograms of solvent present. - Use molality in colligative properties problems, i.e., boiling point elev., freezing point depr., osmotic press.

Molarity, M
$M = \frac{\text{moles solute}}{\text{total moles solution}}$ - Again, don't forget this, you've got to keep track of how adding solute changes the total volume of the solution. - Molarity is almost always used for concentration in chemistry problems. [A] <-- square brackets means the concentration of A in molarity. - Be able to relate moles and volume $MV = n$. (molarity x volume = moles)

Normality, N
$N = (\text{molarity}) (\# \text{ of equivalents})$ - The number of equivalents is just the number of protons an acid/base can donate or accept. Like, HCl has 1 equivalent, H_2SO_4 has 2 equivalents, H_3PO_4 has 3 equivalents, NaOH has 1 equivalent, $\text{Mg}(\text{OH})_2$ has 2 equivalents. Get it? - For strong acid--strong base titration problems you can use normality. $(NV)_{\text{acid}} = (NV)_{\text{base}}$ at the equivalence point

Student Packet: 3.5: Solutions and Colligative Properties: AssessMe questions

- 1) If you wish to find the new volume of a gas which was at 0°C and 700 mm Hg pressure, and conditions were changed to 20°C and 760 mm Hg pressure, by what fraction would you multiply the original volume?
A) $(293 \times 760)/(273 \times 700)$
B) $(273 \times 700)/(293 \times 760)$
C) $(273 \times 760)/(293 \times 700)$
D) $(293 \times 700)/(273 \times 760)$
E) I'm clueless
- 2) If water is the liquid in a barometer instead of mercury, the height difference can be changed to an equivalent mercury expression by:
A) dividing by 13.6
B) multiplying by 13.6
C) adding 13.6
D) subtracting 13.6
E) I'm clueless
- 3) When an electrolyte is dissolved in water to form a solution, the vapor pressure of the solution (compared to pure water):
A) Increases
B) Decreases
C) Remains the same
D) May either increase or decrease
E) I'm clueless
- 4) Which of the following is most soluble in water?
A) SiO_2 B) $\text{CH}_3\text{-O-CH}_3$ C) CaCO_3 D) NaCH_3CO_2 E) I'm clueless
- 5) Which of the following will have the lowest freezing point?
A) 0.15 M glucose
B) 0.30 M sucrose
C) 0.15 M NaCl
D) 0.30 M CH_3COOH
E) I'm clueless
- 6) Which of the following will have the highest boiling point?
A) 0.25 M NaCl
B) 0.50 M glucose
C) 0.25 M NaCH_3CO_2
D) 0.50 M MgBr_2
E) I'm clueless

Student Packet: 3.5: Solutions and Colligative Properties: ShowMe questions

- 1) A solution was prepared by dissolving 12.00 g of ethylene glycol, $\text{C}_2\text{H}_6\text{O}_2$, in 200.0 g of carbon tetrachloride, (CCl_4). Pure CCl_4 boils at 76.5°C . What will be the boiling point of the solution? (K_b for $\text{CCl}_4 = 5.03^\circ\text{C kg/mol}$)

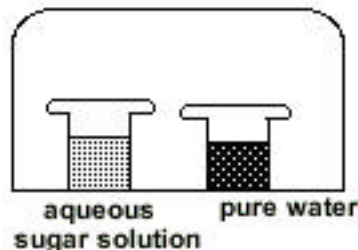
- 2) Calculate the freezing point of a solution prepared by adding 6.00 g NaCl to 35.0 g of H_2O . ($K_F = 1.86^\circ\text{C kg/mol}$)

- 3) A solution is prepared by dissolving 2.75 g of an unknown nonvolatile, nonelectrolyte in water to a volume of 5.00×10^2 mL. The osmotic pressure of the solution at 25°C was measured as 1.05 atm. Calculate the molar mass of the unknown solute.

- 4) Calculate the mass of glycerin, $\text{C}_3\text{H}_8\text{O}_3$, (a nonvolatile nonelectrolyte) that must be added to 5.00×10^2 g H_2O at 25°C to reduce the water vapor pressure by 0.50 torr. (The vapor pressure of pure H_2O at 25°C is 23.76 torr.)

Student Packet: 3.5: Solutions and Colligative Properties: TestMe questions

- 1) A sealed container holds two beakers containing equal volumes of liquid. Beaker (1) contains a sugar solution, while beaker (2) contains pure water.



What will we see after the system reaches equilibrium?

- A) No change, volume in each beaker remains constant.
 B) Beaker (2) will be empty. Beaker (1) will contain twice its original volume.
 C) Beaker (1) will be empty. Beaker (2) will contain twice its original volume.
 D) Both beakers will be empty.
 E) Some water will have evaporated from both beakers, and the volumes will decrease slightly.
- 2) Which of the following aqueous solutions will have the lowest freezing point?
- A) 0.08 m NaCl
 B) 0.10 m HCl
 C) 0.15 m C₁₂H₂₂OH
 D) 0.07 m CaCl₂
 E) 0.19 m C₂H₆O₂
- 3) Ethylene glycol (C₂H₆O₂) is added to water to make antifreeze. What volume of ethylene glycol must be added to 20.0 L of water to make a solution with a freezing point of -25.0°C? (Density of C₂H₆O₂ = 1.11 g/cm³. K_F of water = 1.86°C kg/mol)
- A) 15.0 L B) 20.0 L C) 1.50 L D) 12.0 L E) None of the above
- 4) What concentration of MgCl₂ in water is needed to produce an aqueous solution with an osmotic pressure of 9.60 atm at 30.0°C?
- A) 0.193 M B) 0.386 M C) 0.129 M D) 1.16 M E) 3.90 M
- 5) 12.0 g of a non-volatile nonelectrolyte is dissolved in 125.0 g of water. The aqueous solution was found to have a boiling point of 100.28°C (at 1 atm). What is the molecular mass of the solute? (K_b for water equals 0.51°C kg/mol)
- A) 17.5 g/mol B) 5.27 g/mol C) 52.7 g/mol D) 175 g/mol E) None of the above