Solutions and Colligative Properties: Student Review Notes

Solutions and the process of hydration

When you put a solid (like table salt, NaCl) into a liquid (like H_2O), 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 hydration. Here, take a look:
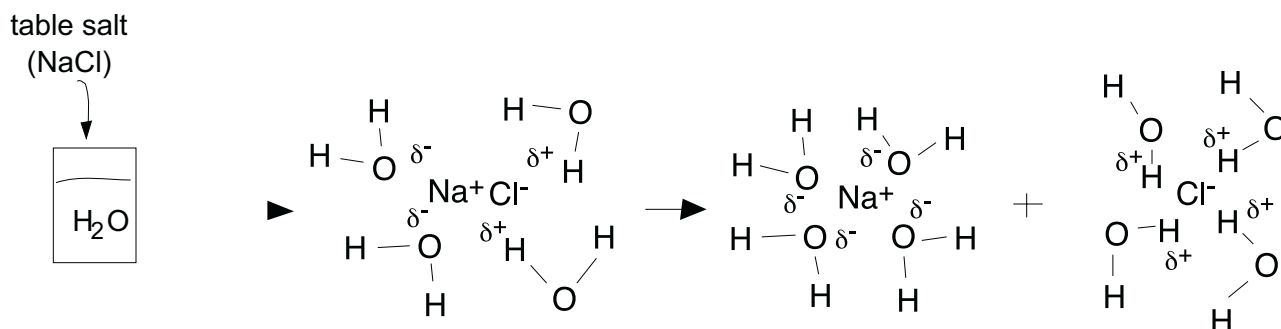
The polarity on the water molecules is shown only for those molecules directly interacting with the solute. δ^+ means a little plus charge and δ^- means a little minus charge.

H_2O 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

Electrolytes are solutions in which ionic molecules (like NaCl) break up into cations and anions.

Nonelectrolytes

Nonelectrolytes are solutions in which neutral molecules (like sugar) are the solute.

Colligative Properties of Solutions

These are properties of solutions that depend primarily on the concentration of solute particles rather than on the nature of the solute particles.

Properties

1. Vapor Pressure Lowering
2. Boiling Point Elevation
3. Freezing Point Depression
3. Osmotic Pressure

Understand that since colligative properties depend only on the concentration of solute particles and not the nature of the particles, all water solutions with the same solute concentration will have the same vapor pressure, boiling point, freezing point, and osmotic pressure.

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concentration units for colligative properties problems

Mole fraction, X_A	Molality, m	Molarity, M
$X_A = \dfrac{\text{moles A}}{\text{total moles solution}}$	$m = \dfrac{\text{moles solute}}{\text{kilograms solvent}}$	$M = \dfrac{\text{moles solute}}{\text{liter of solution}}$
Vapor Pressure Lowering	Boiling Point Elevation Freezing Point Depression	Osmotic Pressure

Vapor Pressure Lowering

This is true for non-volatile solutes. Essentially, the solute molecules are taking spots at the vapor-liquid interface and this reduces the number of solvent molecules that have a change to evaporate. Thus, the vapor pressure is lowered.

$$\Delta P = X_{solute}\ P^{sat}_{solvent}$$

Change in the vapor pressure of the solvent   mole fraction solute   Vapor pressure of pure solvent at the specified temperature

Boiling Point Elevation

This is a direct result of vapor pressure lowering. Remember that a liquid boils when its vapor pressure is equal tp the pressure above it--typically the column of atmosphere sitting on top of it. If the presence of a solute lowers the vapor pressure of the liquid, a higher temperature will be required to reach the boiling point. Again, this is the point at which the vapor pressure of the liquid is equal to the external pressure and why you add salt to water to get a higher boiling temperature.

boiling point elevation constant

Change in boiling point temperature (always positive) — $$\Delta T = i\ k_b\ m$$ — molality

van't hoff factor--the number of particles per molecule of solute

Freezing Point Depression

Here, solute molecules simply interfere with the crystallization process. This is why roads are salted in the winter and antifreeze is used in cars.

freezing point depression constant

Change in freezing point temperature (always positive) — $$\Delta T = i\ k_b\ m$$ — molality

van't hoff factor--the number of particles per molecule of solute

Osmotic Pressure

At a semi-permeable membrane, a solvent will move from the region where it is of greater concentration to the one where it is of lesser concentration. This is osmosi and its just about the statistics of hitting a permeable barrier with different hit frequencies on each side. Osmotic Pressure is the external pressure that would be applied to the region of lower solvent concentration to prevent osmosis.

$$\text{Osmotic Pressure} = \pi = MRT$$

molarity   gas constant   temperature