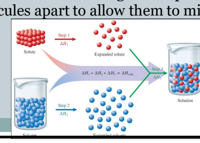
Solutions

CHAPTER 11

Why things dissolve

- DON'T USE LIKE DISSOLVES LIKE AS A JUSTIFICATION!!!!
- College Board won't accept it! They feel that is a mnemonic aid, not a justification!
- First, remember dissolving means pulling the atoms or molecules apart to allow them to mix.



Polar

- Polar molecules dissolve other polar molecules because the positive end of one molecule attracts to the negative end of another molecule. This pulls the solute molecules away from each other and towards the solvent particles.
- Polar molecules are also good at dissolving ionic compounds because the positive end of a molecule attracts to an anion, and a negative end attracts to a cation, pulling the whole structure apart.
- Polar water can even dissolve nonpolar CO_2 and O_2 by inducing a dipole in molecules.

Nonpolar

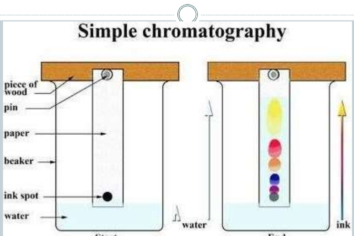
- Nonpolar is much trickier.
- Because polar molecules are more attracted to other polar molecules, then in a mixture of polar and nonpolar molecules the polar will stay together excluding the nonpolar molecules.
- That is why we see a polar and nonpolar layer in a liquid mixture (oil and water or aqueous and organic)
- Due to this separation, nonpolar has very little chance of dissolving in polar.
- Although we say nonpolar dissolves nonpolar, it really only has a chance of doing so because it isn't excluded.
- In many cases, the nonpolar substances doesn't dissolve.

Chromatography

- Separating a solution by *capillary action*
- ~the attraction of a liquid to the surface of a solid, why water "climbs up things"
- For a simple chromatography place ink on chromatography paper and place the paper in a solvent with the ink above the water line.
- The solvent will "climb up" and separate the ink

Chromatography

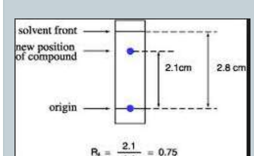
- In chromatography, a **mobile phase** carries something through a **stationary phase**.
- If different constituents have move at different speeds the material will be separated
- In simple paper chromatography the water is the mobile phase, the paper is the stationary phase.



R_f Factor

- R_f value is determined by taking the ratio of distance the substance has traveled compared to the distance the solvent has traveled.
- This R_f factor is compared to a known sample and used to identify unknowns.

R_f factor



Chromatography

- There are several laboratory techniques that use the same principle.
- Thin layer chromatography (TLC) uses an absorbent material like silica gel instead of paper.
- Column chromatography has a stationary phase in a tube.
- Gas chromatography has a gas as the mobile phase.
- Gas chromatography is used in breathalyzer machines to test for DUI's

Frequently used standards of concentration

Measurement	Notation	Generic formula	Typical units
Molarity	M	$\left(\frac{\text{moles solute}}{\text{liters solution}}\right)$	mol/L (or M)
Molality	m	$\left(\frac{\text{moles solute}}{\text{kilograms solvent}}\right)$	mol/kg (or m**)
Mole fraction	χ (chi)	$\left(\frac{\text{moles solute}}{\text{moles solution}}\right)$	(decimal)
Mass percentage	wt%	$\left(\frac{\text{grams solute} \times 100}{\text{grams solution}}\right)$	%

*parts per (ppt, ppm, ppb) is the same as mass percent, except you multiply by a thousand, million or billion

Colligative (Collective) Properties of Solutions

- Colligative properties of a solution are properties that depend on the fact that something is dissolved in solution, not what is dissolved in the solution.
- These properties of a *solution* are always compared against the pure *solvent*.

Nonvolatile nonelectrolytic (ideal) solutions

- **Vapor Pressure Lowering (ΔP).**
- The solution's vapor pressure is always lower than the pure solvent.
- Surface particles consist of some nonvolatile solute particles that have replaced some solvent particles. Therefore, not as many solvent particles are permitted to become a vapor.

Vapor Pressures of Solutions

- Nonvolatile solute lowers the vapor pressure of a solvent.
- Raoult's Law: $P_{soln} = \chi_{solv} P^{\circ}_{solv}$

P_{soln} = observed vapor pressure of solution

χ_{solv} = mole fraction of solvent

P°_{solv} = vapor pressure of pure solvent

Calculations for phase change points

- ΔT = change in temperature
- Boiling point elevation = $BP_{normal} + \Delta T$
- Where $\Delta T = K_b (m)i$
- Freezing Point Depression = $FP_{normal} - \Delta T$
- Where $\Delta T = K_f (m)i$
- K_b is the ebulliscopic constant
- K_f is the cyroscopic constant
- m is the molality of the solution
- i is the Van't Hoff factor

Van't Hoff Factor (i)

- Colligative properties means it doesn't matter what the solute is.
- Some things when dissolved dissociate (ionic compounds), which, if you don't care what the solute is technically would increase the molality.
- $NaCl_{(s)} \rightarrow Na^+_{(aq)} + Cl^-_{(aq)}$
- Sodium chloride dissociates into 2 things
- So it's Van't Hoff factor is 2
- $C_6H_{12}O_{6(s)} \rightarrow C_6H_{12}O_{6\,(aq)}$
- Glucose is a covalent compound that doesn't dissociate, so it's Van't Hoff factor is 1

Boiling Point Elevation (ΔT_b).

- The boiling point of ethanol is 78.5° C. What is the boiling point of a solution of 3.4 g vanillin (*M* = 152.14 g/mol) in 50.0 g ethanol? (K_b of ethanol = 1.22 C/m).

Boiling Point Elevation

- A solution was prepared by dissolving 18.00 g glucose in 150.0 g water. The resulting solution was found to have a boiling point of 100.34° C. Calculate the molar mass of glucose. Glucose is a molecular solid that is present as individual molecules in solution.
- K_b of water = 0.512 C/m

Osmosis

- Osmosis is the diffusion of water across a semipermeable membrane, Like a cell wall.
- Water can pass through, solute particles can not pass through.
- Water will always travel to equal the concentration out.
- If a cell is in a higher concentration salt solution (hypertonic), water will travel out to lower the concentration, causing the cell to shrivel.
- If a cell is in a lower concentration salt solution (hypotonic), water will travel in to raise the concentration, causing the cell to expand.

Osmotic Pressure

- Osmotic pressure (π) is the pressure that results from the inability of solute particles to cross a semipermeable membrane; the pressure required to prevent the net movement of solvent across the membrane.
- $\pi = iMRT$

π	=	osmotic pressure (atm)
M	=	molarity of the solution
R	=	gas law constant
T	=	temperature (Kelvin)

Reverse Osmosis

- Reverse osmosis is a method to purify water.
- It is especially useful for desalination (removing salt) from water.
- You force water across a semipermeable membrane by using a pump pressuring the water such that the water pressure is greater than the osmotic pressure.
- This causes the water to cross the semipermeable membrane leaving dissolved solute behind.

Osmosis Problem

- $\pi = iMRT$
- To determine the molar mass of a certain protein, 1.00×10^{-3} g of it was dissolved in enough water to make 1.00 mL of solution. The osmotic pressure of this solution was found to be 1.12 torr at 25° C. Calculate the molar mass of the protein.

Volatile nonelectrolytic solutions

- When a solution contains two volatile components, both contribute to the total vapor pressure, but not necessarily in equal amounts.
- Equal amounts of liquid do not produce equal amounts of vapor.

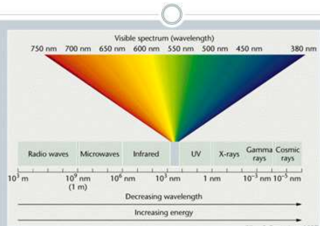
Solutions

- Most solutions are **clear**.
- Copper solutions are blue.
- Nickel solutions are green
- Iron III is yellow to orange.
- (Iron II is light blue)
- Cobalt is pink
- Permanganate is purple
- Chromate is yellow
- Dichromate is orange
- Metal coordination complexes are a variety of colors.

Color

- ---quick physics break---
- What is color?
- White light is all colors of light put together
- You only see light that hits your eye.
- Light is composed of photons. The frequency, wavelength and energy of these photons are related.
- Visible light is a wavelength range of 400-700 nm.
- ROY G BIV is the order
- Red is low energy, high wavelength, low frequency
- Violet is high energy, low wavelength, high frequency

The EM spectrum



Absorption

- Some photons can be absorbed by atoms.
- The photons (packets of energy) excite the atom, causing its electrons to jump up energy levels.
- Only particular photons can be absorbed. They have to resonate with the atom. That means some photons are too high energy to be absorbed, other are too low.
- For copper to be a blue solution…
- (white light is all colors) it has to absorb lower energy (red orange yellow green) and higher energy (violet) but allow the middle range (blue) to pass through.

We see light that hits our eye

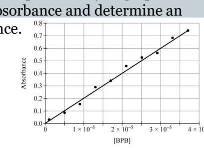
- Since all colors of light have been removed except blue, we say the solution is blue (even though is absorbing everything but blue).
- Photosynthesis is a reaction powered by the absorption of visible light.
- What color would be bad to use as a grow light?
- Green, it is reflected by the plant (you can tell because you see it), all other colors are absorbed and used to power the reaction.

Beer's Law

- There are a couple of factors that determine how much light will be absorbed.
- A - Absorbance
- ε - the absorptivity constant of the solution
- b - the path length of the light source (how wide the cuvette is), cm
- c - concentration of the solution, M
- A = ε b c
- You can also calculate the transmittance (the reverse of absorbance of a solution by
- A = 2 – log (%T)

Beer's Law Determination

- Normally for Beer's law problems, you graph known concentrations vs absorbance and determine an unknown's absorbance.



(d) Based on the best-fit line shown in the graph, what is the approximate absorbance of a solution in which $[BPB] = 3.5 \times 10^{-5} M$?

(e) A student measures the absorbance of a solution of BPB of unknown concentration in order to determine the [BPB] in the solution using the calibration plot above. If a fingerprint remains on the cuvette and in the path of light in the spectrophotometer during the measurement, what would be the effect on the estimated molarity of BPB? Explain your reasoning.

More Beer's law

- It is important to make sure the light source going though the substance will be absorbed by the solution.
- Copper is a blue solution.
- Blue would be a poor choice of light to check for absorbance because blue it isn't absorbed.
- They have asked, what do you need to change if you switched from a solution of blue food coloring to red food coloring?
- You need to change the wavelength of light being measured.