MOLARITY and the other concentration units

- To convert between molarity and the other three concentration units we've studied, you have to know more about the solution. For example:

molarity $\frac{\text{moles A}}{\text{L solution}}$ $\longrightarrow$ molality $\frac{\text{moles A}}{\text{kg solvent}}$

* To perform this conversion, you can assume a liter of solution, which will give you the number of moles present. But you've then got to have a way to convert the volume of SOLUTION to the mass of the SOLVENT. How?

* You need DENSITY (which depends on temperature). The density of the solution will allow you to find the total mass of the solution.

* If you subtract out the mass of the SOLUTE, then what you have left is the mass of the SOLVENT. Express that in kilograms, and you have all the information you need to find molality!

* You'll run into the same situation when you use any of the other mass or mole based units. DENSITY is required to go back and forth between MOLARITY and these units.

Example: If a solution is 0.688 m citric acid, what is the molar concentration (M) of the solution? The density of the solution is 1.049 g/mL

$H_3C_6H_5O_7$: 192.125 g/mol

$$\frac{0.688 \text{ mol CA}}{\text{kg solvent}} \longrightarrow \frac{\text{mol CA}}{\text{L solution}}$$

molality (m) molarity (M)

* Assume I have a solution with 1 kg solvent! This means it contains 0.688 moles of CA.

* Now, I need to find the volume of the solution! How? Use the density of the solution, but first I need to find the MASS of the SOLUTION.

$$0.688 \text{ mol CA} \times \frac{192.125 \text{ g}}{\text{mol}} = 132.182 \text{ g}$$

$$1000 \text{ g solvent} + 132.182 \text{ g CA} = 1132.182 \text{ g solution}$$

Find the volume of the solution using mass and density.

$$1132.182 \text{ g solution} \times \frac{\text{mL}}{1.049 \text{ g}} = 1079.30 \text{ mL} = 1.07930 \text{ L}$$

Find the molarity using the moles CA and the solution volume (in liters)

$$M = \frac{0.688 \text{ mol CA}}{1.07930 \text{ L}} = \boxed{0.637 \underline{M} \text{ CA}}$$

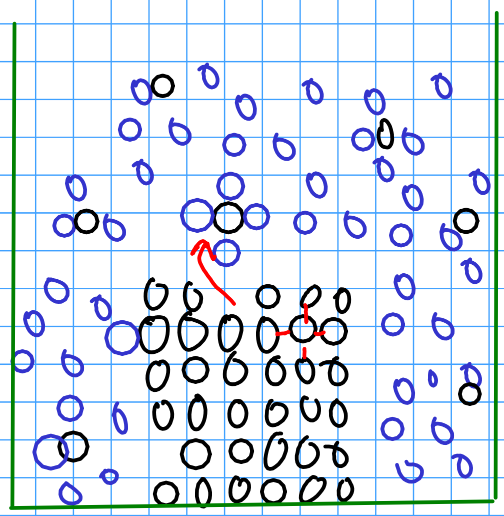
HOW THINGS DISSOLVE

- Let's look at how things dissolve into water, since aqueous solutions are quite common.

sucrose (table sugar)

$$C_{12}H_{22}O_{11}(s) \underset{}{\overset{H_2O}{\rightleftharpoons}} C_{12}H_{22}O_{11}(aq)$$

... what happens?



- Water molecules pull the sugar molecules out of the sugar crystal and into solution.

- Attractions between sugar molecules and water allow this to happen.

- The solubility of the sugar depends on how well water and sugar interact (HYDRATION) versus how well the sugar molecules are held in the crystal (LATTICE ENERGY)

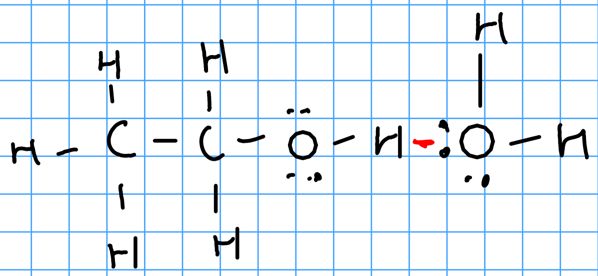
- "like dissolves like": Substances held together by similar (or at least compatible) kinds of attractive forces can dissolve in each other. Substances that are held together by very different kinds of attractive forces will not dissolve in one another!

Consider WATER:

HYDROGEN BONDS

↓

Water mixes well with other substances that can hydrogen bond, like ETHANOL!



POLAR

↓

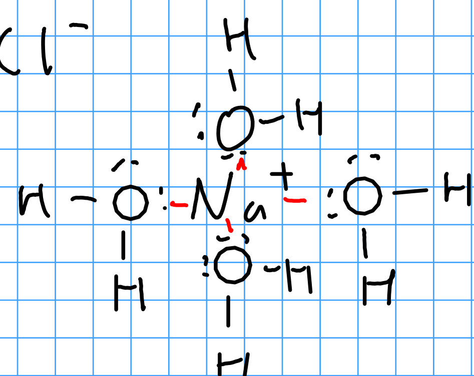
Water can dissolve polar substances!

(SUCROSE is polar!)

↓

Since IONIC BONDS are also interactions between opposite charges (You can think of an ionic bond here as an extreme case of dipole-dipole interaction), many IONIC SUBSTANCES will also dissolve in water!

$Na^+ - Cl^-$



SMALL (little London force)

↓

large and/or nonpolar solutes do not dissolve well in water!

(example: OILS and WAXES)

MOLECULAR AND IONIC SOLUTIONS

- MOLECULAR solutions:

Contain MOLECULES dissolved in one another.

(1) - Any mixture of GASES

- all gases mix with one another, since gas molecules (effectively) do not interact with one another.

(2) - Liquids

- Liquids dissolve well in one another only if they are held together by similar kinds of forces

(3) - Solids and liquids

- MOLECULAR SOLIDs will dissolve well in liquids if they are held together by similar forces.

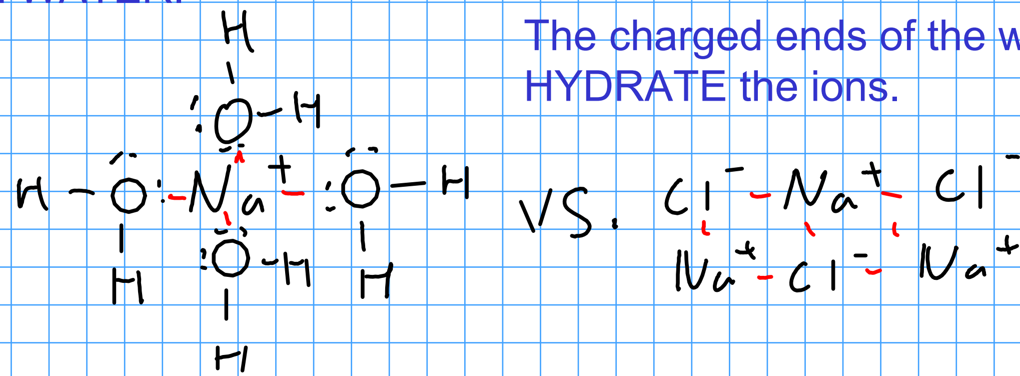
- IONIC SOLIDS will sometimes dissolve in POLAR liquids, but not in nonpolar liquids

- COVALENT NETWORK solids don't generally dissolve well in other substances

IONIC solutions

- form when ions from IONIC SUBSTANCES interact with POLAR solvents - often WATER.

The charged ends of the water molecule HYDRATE the ions.



- The solubility of an ionic compound depends on whether HYDRATION (attraction of water molecules for an ion) is greater than LATTICE ENERGY - the attrraction of ions in a crystal lattice for one another..

- SMALLER IONS are usually easier to enclose in water than larger ones, and ions with larger charges are attracted to water molecules.

- But solubility is also determined by LATTICE ENERGY - which holds the solid ionic compound together. Ions with high charges tend to be strngly attracted to other ions in a crystal, meaning lattice energy is high. Smaller ions also tend to have higher lattice energies. Lattice energy and hydroation are competing trends!

COLLIGATIVE PROPERTIES

- properties unique to solutions.

- depend only on the CONCENTRATION of a solution and not the IDENTITY of the solute**

**ionic solutes: Remember that they dissociate into MULTIPLE IONS!

1. Freezing point depression
   - The freezing temperature of a SOLUTION gets lower as the CONCENTRATION of a solution increases.

2. Vapor pressure lowering
   - The vapor pressure of a solution (pressure of sovent vapor over a liquid surface) goes DOWN as solution concentration goes UP

3. Boiling point elevation
   - The boiling temperature of a solution increases as the concentration of the solution increases.

4. Osmotic pressure
   - The pressure required to PREVENT the process of osmosis

FREEZING POINT DEPRESSION

$$\Delta T_f = K_f \times C_m$$

- C_m — concentration of solute (molality)
- K_f — Freezing point depression constant (for SOLVENT)
- ΔT_f — Freezing point depression: The amount the freezing temperature is LOWERED by the solute.

- Applications: In chemistry, this effect is often used to determine the molecular weight of an unknown molecule.

A solution of 2.500g of unknown dissolved in 100.0 g of benzene has a freezing point of 4.880 C. What is the molecular weight of the unknown?

$K_{f,\,benzene} = 5.065\ ^{\circ}C/m$, $T_{f,\,benzene} = 5.455^{\circ}C$ psol

$\Delta T_f = K_f \times C_m$

$C_m = \frac{\text{moles unknown}}{\text{kg solvent}}$

To find the MW, I need to know how many moles of the unknown I weighed out initially. To get moles, I can find out what the MOLAL concentration of the solution is!

Find FPD $\Delta T_f = 5.455^{\circ}C - 4.880^{\circ}C = 0.575^{\circ}C$

Kf is a constant $K_f = 5.065\ ^{\circ}C/m$

Solve for Cm

$$\Delta T_f = K_f \times C_m$$

$$0.575^{\circ}C = (5.065\ ^{\circ}C/m) \times C_m$$

$$0.1135\ m = C_m$$

Calculate moles of unknown "U"

$$0.1000\ kg\ benzene \times \frac{.1135\ mol\ U}{kg\ benzene} = 0.01135\ mol\ U$$

Calculate molecular weight

$$MW = \frac{2.500\,g}{0.01135\,mol} = \boxed{220.\ g/mol}$$