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 "CA"

$$\frac{0.688 \text{ mol CA}}{1 \text{ kg solvent}} \longrightarrow \frac{? \text{ mol CA}}{? \text{ L solution}}$$

molality (m) molarity (M)

* Assume 1 kg of solvent, meaning that the number of moles of CA is 0.688 mol.
* Next, find the volume of the solution. Use the density of the solution, but there's a catch!
* We'll have to calculate the total mass of the SOLUTION - meaning the mass of the solvent (1000 g here) PLUS the mass of the CA solute.

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

mass solution = 1000 g solvent + 132.182 g CA = 1132.182 g

* Now, we can use the density!

$$1132.182 \text{ g} \times \frac{\text{mL}}{1.049 \text{ g}} \times \frac{10^{-3} \text{ L}}{\text{mL}} = 1.079296 \text{ L solution}$$

* Divide the moles CA (0.688 mol) and the volume of solution (1.079296 L) to get MOLARITY (M)

$$\frac{0.688 \text{ mol CA}}{1.079296 \text{ L solution}} = \boxed{0.637 \text{ } \underline{M} \text{ CA}}$$

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL
Find: molality, mole fraction, molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

$$\frac{8.50\text{ g } NH_4Cl}{100\text{ g solution}} \longrightarrow \frac{?\text{ mol } NH_4Cl}{?\text{ kg solvent}}$$

mass percent

molality

mass solvent: $100\text{g} - 8.5\text{g} = 91.5\text{g } H_2O$

moles ammonium chloride: $8.50\text{g } NH_4Cl \times \frac{\text{mol}}{53.491\text{ g}} = 0.15891\text{ mol } NH_4Cl$

$$m = \frac{0.15891\text{ mol}}{0.0915\text{ kg}} = \boxed{1.74\text{ m } NH_4Cl}$$

$$\frac{8.50\text{ g } NH_4Cl}{100\text{ g solution}} \longrightarrow \frac{\text{mol } NH_4Cl}{\text{mol } NH_4Cl + \text{mol } H_2O}$$

mol NH_4Cl ← 0.15891 mol

mass percent

mol water: $91.5\text{ g } H_2O \times \frac{\text{mol } H_2O}{18.02\text{ g } H_2O} = 5.07769\text{ mol } H_2O$

$$X_{NH_4Cl} = \frac{0.15891\text{ mol}}{0.15891\text{ mol} + 5.07769\text{ mol}} = \boxed{0.0303 = X_{NH_4Cl}}$$

An aqueous solution is 8.50% ammonium chloride by mass. The density of the solution is 1.024 g/mL. Find: molality, mole fraction, molarity.

NH_4Cl : 53.491 g/mol H_2O: 18.016 g/mol

$$\frac{8.50\text{ g } NH_4Cl}{100\text{ g solution}} \longrightarrow \frac{\text{mol } NH_4Cl}{\text{L solution}}$$

mass percent → molarity

mol NH_4Cl ← 0.15891 mol NH_4Cl (previous calculation)

volume of solution:

$$100\text{ g soln} \times \frac{\text{mL}}{1.024\text{ g}} \times \frac{10^{-3}\text{ L}}{\text{mL}} = 0.09765625\text{ L}$$

Use density! (for 1.024 g)

$$\underline{M} = \frac{0.15891\text{ mol } NH_4Cl}{0.09765625\text{ L}} = \boxed{1.63\ \underline{M}\ NH_4Cl}$$

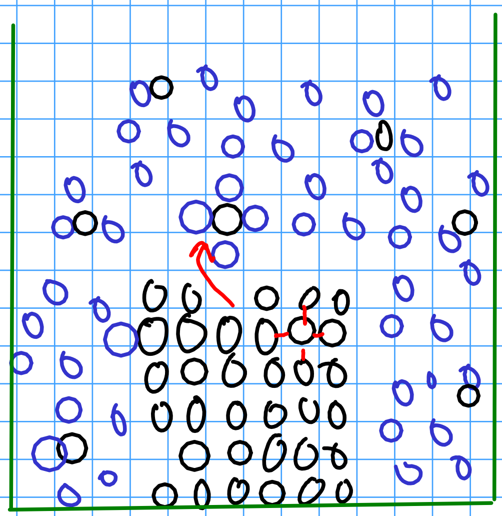
HOW THINGS DISSOLVE

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

sucrose (table sugar)

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

... 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)

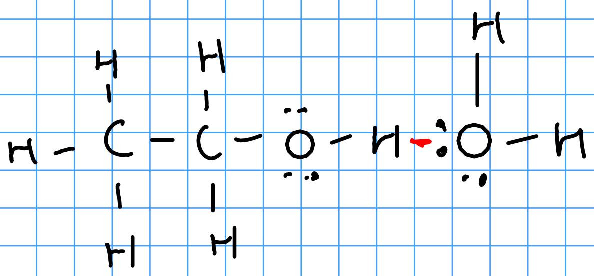
- "like dissolves like": Substances held together by similar (or at least compatible) kinds of attractive forces can dissolve in each other. Substances that are held together by very different kinds of attractive forces will not dissolve in one another!

Consider WATER:

HYDROGEN BONDS

↓

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



POLAR

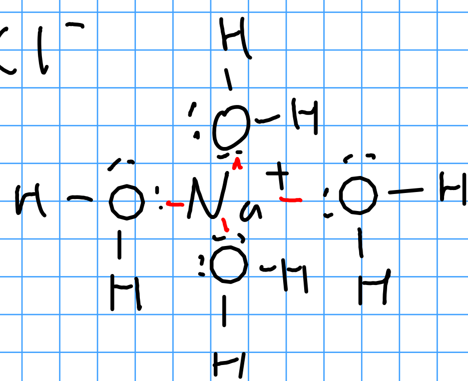
↓

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!

$Na^+ - Cl^-$



"ion-dipole" interactions

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

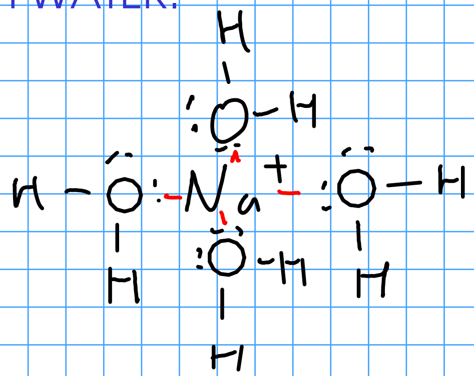
- MOLECULAR SOLIDs will dissolve well in liquids if they are held together by similar forces.

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

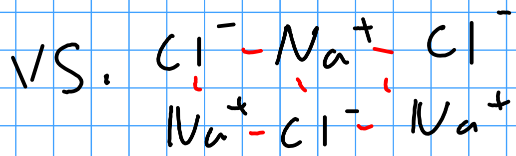
- COVALENT NETWORK solids don't generally dissolve well in other substances

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!