More on MOLARITY

To prepare a solution of a given molarity, you generally have two options:

1. Weigh out the appropriate amount of solute, then dilute to the desired volume with solvent (usually water)"

"stock solution"

2. Take a previously prepared solution of known concentration and DILUTE it with solvent to form a new solution

- Use DILUTION EQUATION

The dilution equation is easy to derive with simple algebra.

$$M \times V$$

$$\frac{mol}{L} \times L = \text{moles solute}$$

... but when you dilute a solution, the number of moles of solute REMAINS CONSTANT. (After all, you're adding only SOLVENT)

$$M_1 V_1 = M_2 V_2$$

Since the number of moles of solute stays the same, this equality must be true!

before diution

after dilution

$$M_1V_1 = M_2V_2$$ ... the "DILUTION EQUATION"

M_1 = molarity of concentrated solution

V_1 = volume of concentrated solution

M_2 = molarity of dilute solution

V_2 = volume of dilute solution

Note: V2 is the TOTAL VOLUME OF SOLUTION MADE, and NOT the volume of water to add!

The volumes don't HAVE to be in liters, as long as you use the same volume UNIT for both V_1 and V_2

Example: Take the 0.500 M sodium sulfate we discussed in the previous example and dilute it to make 150. mL of 0.333 M solution. How many mL of the original solution will we need to dilute?

$$M_1V_1 = M_2V_2$$

$$(0.500\ M)V_1 = (0.333\ M)(150.\ mL)$$

$$V_1 = \boxed{99.9\ mL\ of\ 0.500\ \underline{M}\ Na_2SO_4}$$

Take 99.9 mL of 0.500 M stock solution, and add water until the total volume of solution is 150. mL.

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 $\qquad\qquad\qquad\qquad$ molality

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

* 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 "CA"

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

molality (definition)

molarity (definition)

1 - ASSUME A BASIS of 1 kg of solvent. Each kilogram of solvent contains 0.688 moles CA.

2 - Find VOLUME OF SOLUTION. We know the density of solution, but we do not yet know the MASS OF SOLUTION. To use density, we need to know the total mass of solution - including solute. Find mass CA from formula weight and number of moles.

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

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

Now, find the volume:

$$1132.182 \text{g solution} \times \frac{\text{mL}}{1.049 \text{g}} \times \frac{10^{-3} \text{L}}{\text{mL}} = 1.07929647 3\text{L}$$

$$M = \frac{\text{mol CA}}{\text{L solution}} = \frac{0.688 \text{ mol CA}}{1.079296473 \text{L}} = \boxed{0.637 \text{ M CA}}$$

66 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

Find molality:

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

mass percent molality

Find mol ammonium chloride

$$8.50 \text{ g } NH_4Cl \times \frac{\text{mol } NH_4Cl}{53.491 \text{ g } NH_4Cl} = 0.158905236 4 \text{ mol } NH_4Cl$$

Find mass water:

$$100 \text{ g solution} - 8.50 \text{ g } NH_4Cl = 91.50 \text{ g } H_2O = 0.09150 \text{ kg } H_2O$$

Molality:

$$\frac{0.1589052364 \text{ mol } NH_4Cl}{0.09150 \text{ kg } H_2O} = \boxed{1.74 \text{ m } NH_4Cl}$$

Find mole fraction:

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

mass percent

mole fraction
(ammonium chloride)

We already know the moles ammonium chloride in 100 g solution, so all we need to find is the moles of water. We already know mass water, so all we need to do is to convert that number to moles.

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

Find moles water:

$$91.50\,g\ H_2O \times \frac{mol\ H_2O}{18.016\,g\ H_2O} = 5.078818828\ mol\ H_2O$$

$$X_{NH_4Cl} = \frac{0.158905236\,4\ mol\ NH_4Cl}{0.1589052364\ mol\ NH_4Cl + 5.078818828\ mol\ H_2O} = \boxed{0.0303}$$

Find molarity:

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

mass percent molarity

We already know the mol ammonium chloride from previous work, so all we need to do is to find the volume of the solution in liters.

Find volume solution:

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

$$M = \frac{0.1589052364\ mol\ NH_4Cl}{0.09765625\,L} = \boxed{1.63\ \underline{M}\ NH_4Cl}$$

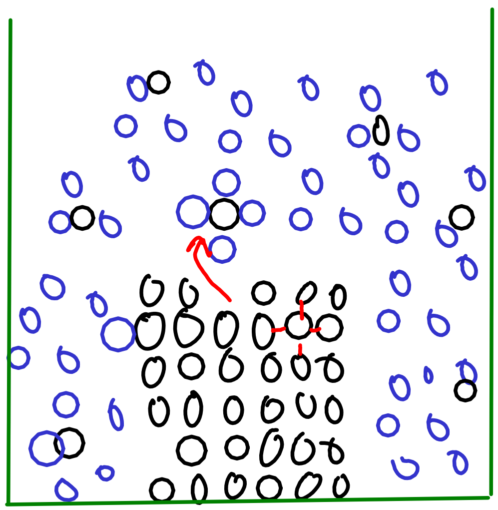
HOW THINGS DISSOLVE

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

sucrose (table sugar)

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

... 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)

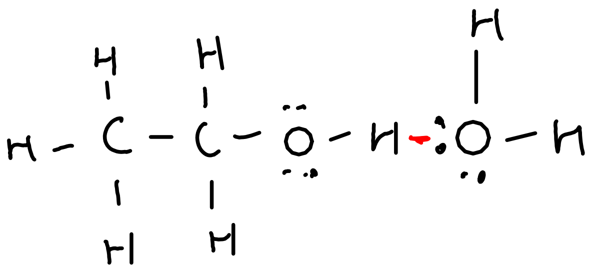
- "like dissolves like": Substances held together by similar (or at least compatible) kinds of attractive forces can dissolve in each other. Substances that are held together by very different kinds of attractive forces will not dissolve in one another!

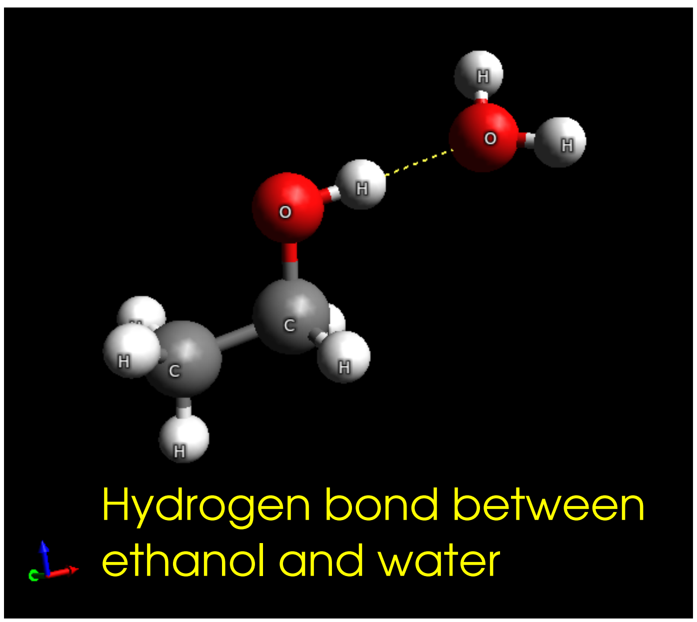
Consider WATER:

HYDROGEN BONDS

↓

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





Hydrogen bond between ethanol and water

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!

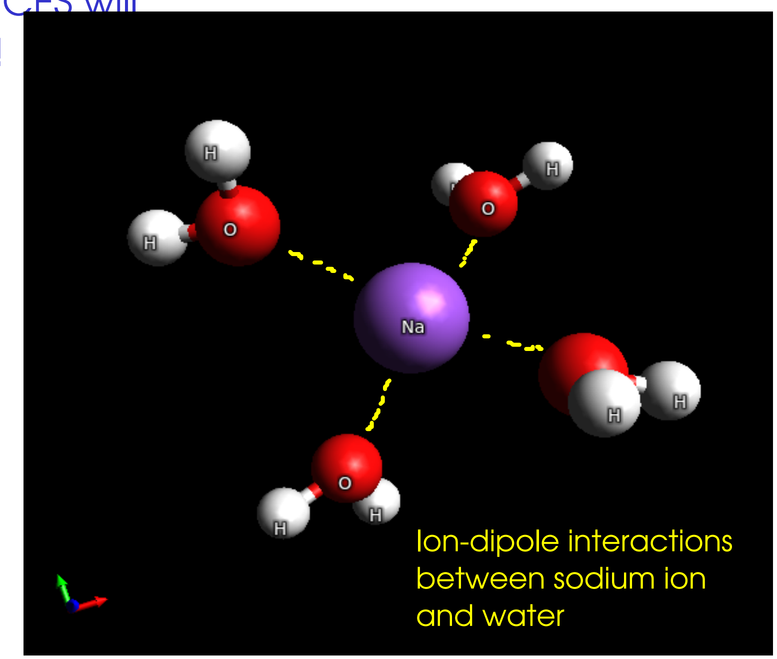
$Na^+ - Cl^-$

SMALL (little London force)

↓

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

(example: OILS and WAXES)



Ion-dipole interactions between sodium ion and water

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

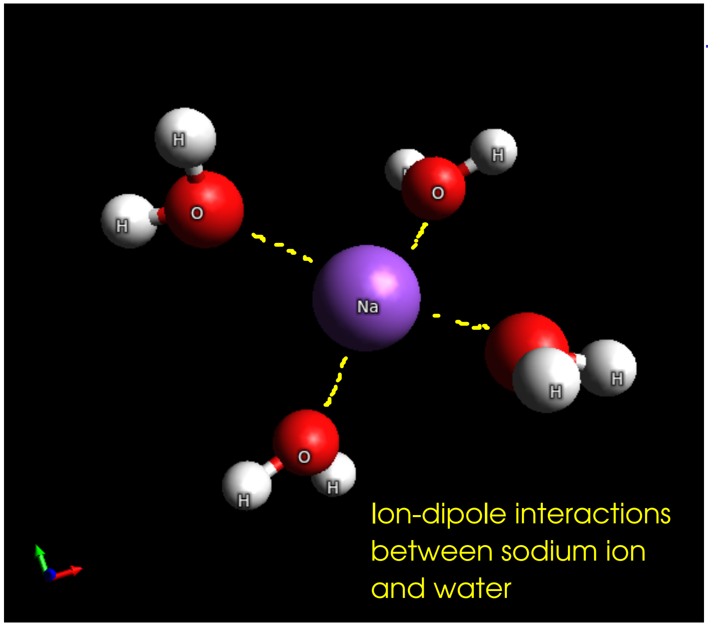
- MOLECULAR SOLIDS will dissolve well in liquids if they are held together by similar forces.

- 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.

vs. $Cl^- - Na^+ - Cl^-$
$Na^+ - Cl^- - Na^+$

- 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 strongly attracted to other ions in a crystal, meaning lattice energy is high. Smaller ions also tend to have higher lattice energies. Lattice energy and hydration 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