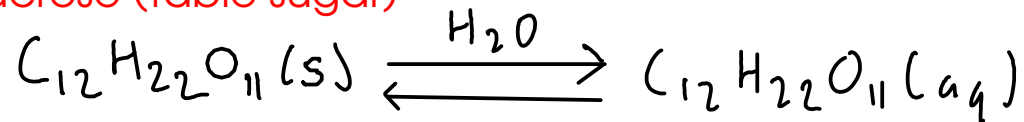


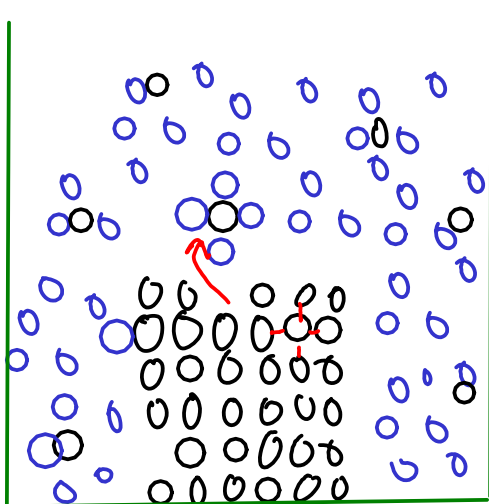
68 HOW THINGS DISSOLVE

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

sucrose (table sugar)



... 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)

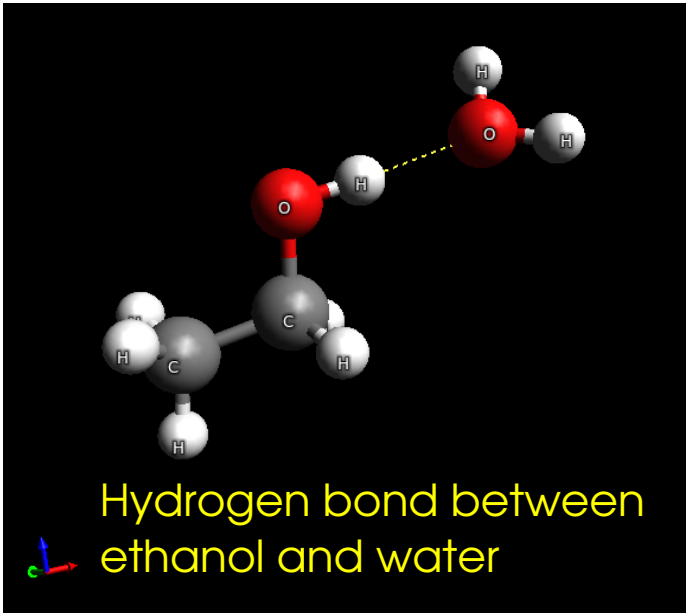
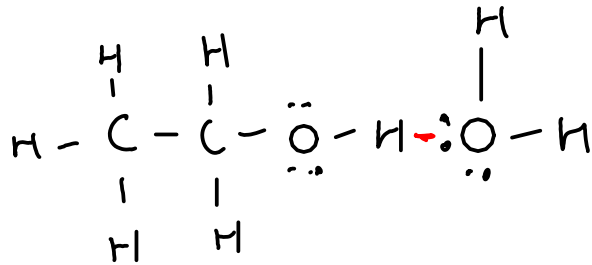
- "like dissolves like": Substances held together by similar (or at least compatible) kinds of attractive forces can dissolve in each other. Substances that are held together by very different kinds of attractive forces will not dissolve in one another!

Consider WATER:

HYDROGEN BONDS



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



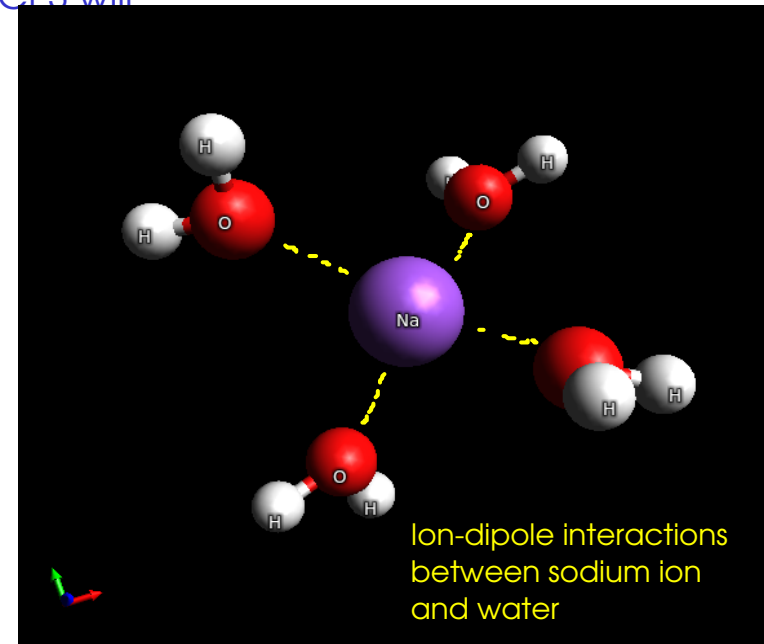
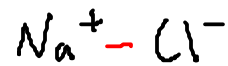
POLAR



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!



SMALL (little London force)



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

(example: OILS and WAXES)

- 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

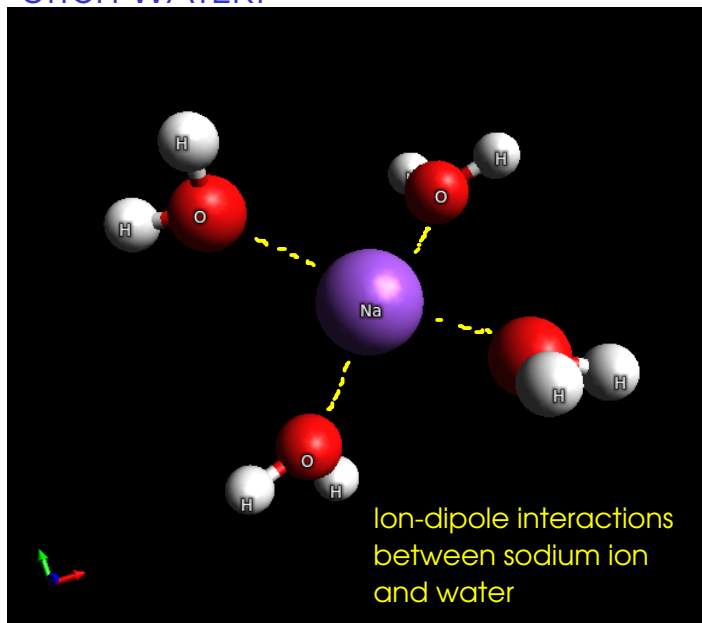
- MOLECULAR SOLIDS will dissolve well in liquids if they are held together by similar forces.

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

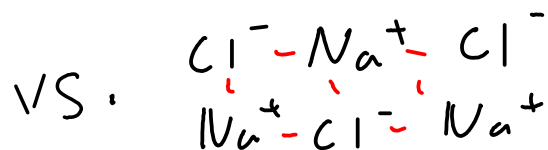
- COVALENT NETWORK solids don't generally dissolve well in other substances

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 attraction 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!

72 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 solvent 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

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

└ concentration of solute (molality)

└ Freezing point depression constant (for SOLVENT)

└ 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?

$$K_{f, \text{benzene}} = 5.065 \text{ } ^\circ\text{C}/m, \quad T_{f, \text{benzene}} = 5.485 \text{ } ^\circ\text{C} \quad \left(\begin{array}{l} \text{see} \\ \text{p 500} \end{array} \right)$$

$$\Delta T_f = K_f \times C_m \quad \approx \quad \frac{\text{mol unknown}}{\text{kg benzene}}$$

$5.065 \text{ } ^\circ\text{C}/m$

$5.485 \text{ } ^\circ\text{C} - 4.880 \text{ } ^\circ\text{C} = 0.575 \text{ } ^\circ\text{C}$

To find MOLECULAR WEIGHT, we need to know both the mass of the unknown sample AND how many moles of unknown are present. If we find C_m , we can find the number of moles!

So, we calculate the MOLAL CONCENTRATION based on the freezing point depression

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

$$C_m = 0.1135241856 \frac{\text{mol unkr}}{\text{kg benz}} \quad (\text{molality})$$

To find moles unknown, multiply by the mass of benzene!

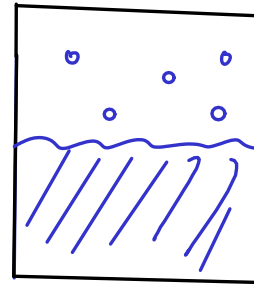
$$0.1135241856 \frac{\text{mol unkr}}{\text{kg benz}} \times 0.1000 \text{ kg benz} = 0.01135241856 \text{ mol unknowns}$$

Find molecular weight:

$$MW = \frac{\text{mass unkr}}{\text{mol unkr}} = \frac{2.500 \text{ g unknown}}{0.01135241856 \text{ mol unknowns}} = \boxed{220. \text{ g/mol}}$$

75 VAPOR PRESSURE LOWERING

- Described by RAOULT'S LAW



P_A = partial pressure of the VAPOR of solvent molecules.

$$P_A = P_A^* \times X_A$$

mole fraction of component A

vapor pressure of pure component A (depends on temperature)

partial pressure of component A in a solution

... but component "A" above is actually the SOLVENT. If we want to describe this as a colligative property, we want to express Raolt's law in terms of the SOLUTE! Assuming a two-component mixture, we get...

$$\Delta P = P_A^* \times X_B$$

mole fraction of component B (the SOLUTE in a two-component mixture)

Vapor pressure lowering. This is the DECREASE in the vapor pressure of the solvent due to the presence of solute.

76 BOILING POINT ELEVATION

- Since the vapor pressure is lowered by the presence of a solute, AND since boiling occurs when the vapor pressure of a liquid equals the external pressure - solutes also cause BOILING POINT ELEVATION.

- The equation for boiling point elevation looks almost exactly like the equation for the freezing point depression, and is used in almost the same way.

$$\Delta T_b = K_b \times C_m$$

ΔT_b — Boiling point elevation: The amount the boiling temperature is RAISED by the solute.

K_b — Boiling point elevation constant (for SOLVENT) (psu)

C_m — concentration of solute (molality)

What is the boiling point of a solution that contains 2.817 g of molecular sulfur (S_8) dissolved in 100.0 grams of acetic acid?

$$T_b = 118.5^\circ\text{C} \quad K_b = 3.08^\circ\text{C}/m \quad (\text{see p500 for data})$$

$$\Delta T_b = \frac{K_b \times C_m}{3.08^\circ\text{C}/m}$$

$$C_m = \frac{\text{mol } S_8}{\text{kg } \text{HC}_2\text{H}_3\text{O}_2} = 0.1000 \text{ kg } \text{HC}_2\text{H}_3\text{O}_2$$

Next, let's determine the moles of sulfur - we already know the mass. Then, find C_m and calculate boiling point elevation.

$$S_8: 8 \times 32.07 = 256.56 \text{ g } S_8 = \text{mol } S_8$$

$$2.817 \text{ g } S_8 \times \frac{\text{mol } S_8}{256.56 \text{ g } S_8} = 0.0109798877 \text{ mol } S_8$$

Find C_m :

$$C_m = \frac{0.0109798877 \text{ mol } S_8}{0.1000 \text{ kg } \text{HC}_2\text{H}_3\text{O}_2} = 0.1097988775 m \text{ } S_8$$

Find boiling point ELEVATION:

$$\Delta T_b = (3.08^\circ\text{C}/m)(0.1097988775 m \text{ } S_8) = 0.338^\circ\text{C}$$

Find the BOILING POINT by adding the elevation to the boiling point of pure solvent:

$$T_{b, \text{solution}} = 118.5^\circ\text{C} + 0.3382^\circ\text{C} = \boxed{118.8^\circ\text{C}}$$