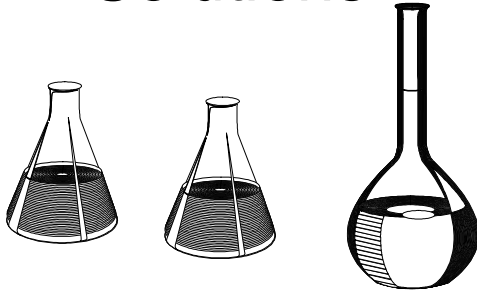


# Solutions



## Occur in all phases

- ◆ The solvent does the dissolving.
- ◆ The solute is dissolved.
- ◆ There are examples of all types of solvents dissolving all types of solvent.
- ◆ We will focus on aqueous solutions.

## Ways of Measuring

- ◆ Molarity =  $\frac{\text{moles of solute}}{\text{Liters of solute}}$
- ◆ % mass =  $\frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100$
- ◆ Mole fraction of component A

$$\chi_A = \frac{N_A}{N_A + N_B}$$

## Ways of Measuring

- ◆ Molality =  $\frac{\text{moles of solute}}{\text{Kilograms of solvent}}$
- ◆ Molality is abbreviated *m*
- ◆ Normality - read but don't focus on it.
- ◆ It is molarity x number of active pieces

## Energy of Making Solutions

- ◆ Heat of solution ( $\Delta H_{\text{soln}}$ ) is the energy change for making a solution.
- ◆ Most easily understood if broken into steps.
  - ◆ 1. Break apart solvent
  - ◆ 2. Break apart solute
  - ◆ 3. Mixing solvent and solute

## 1. Break apart Solvent

- ◆ Have to overcome attractive forces.  
 $\Delta H_1 > 0$

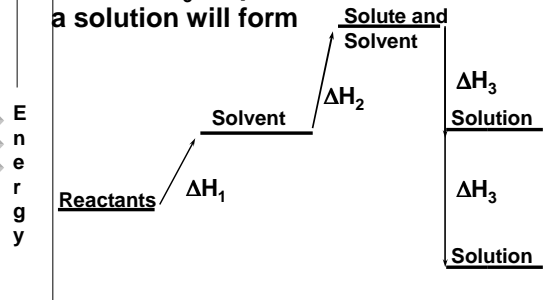
## 2. Break apart Solute.

- ◆ Have to overcome attractive forces.  
 $\Delta H_2 > 0$

### 3. Mixing solvent and solute

- ◆  $\Delta H_3$  depends on what you are mixing.
- ◆ If molecules can attract each other  $\Delta H_3$  is large and negative.
- ◆ Molecules can't attract-  $\Delta H_3$  is small and negative.
- ◆ This explains the rule "Like dissolves Like"

- ◆ Size of  $\Delta H_3$  helps determine whether a solution will form



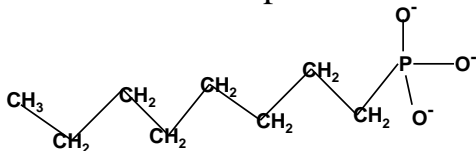
### Types of Solvent and solutes

- ◆ If  $\Delta H_{\text{soln}}$  is small and positive, a solution will still form because of entropy.
- ◆ There are many more ways for them to become mixed than there is for them to stay separate.

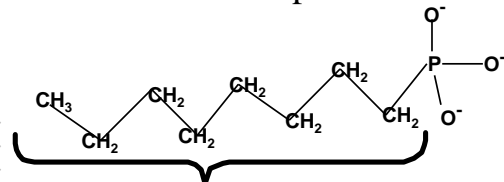
### Structure and Solubility

- ◆ Water soluble molecules must have dipole moments -polar bonds.
- ◆ To be soluble in nonpolar solvents the molecules must be non polar.
- ◆ Read Vitamin A - Vitamin C discussion pg. 509

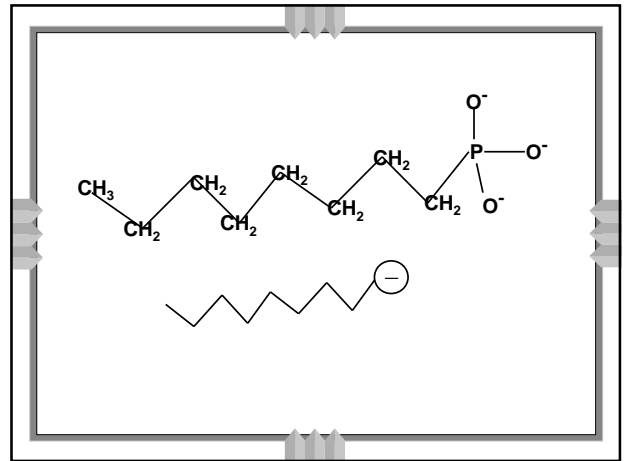
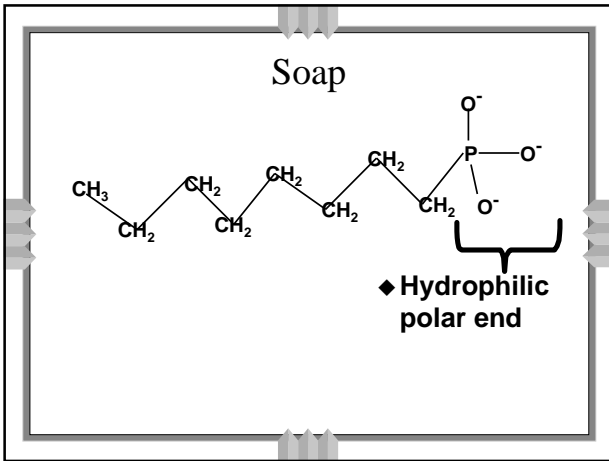
### Soap



### Soap



- ◆ Hydrophobic non-polar end



- ◆ A drop of grease in water
- ◆ Grease is non-polar
- ◆ Water is polar
- ◆ Soap lets you dissolve the non-polar in the polar.

**Hydrophobic ends dissolve in grease**

**Hydrophilic ends dissolve in water**

- ◆ Water molecules can surround and dissolve grease.
- ◆ Helps get grease out of your way.

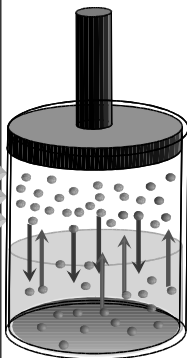
### Pressure effects

- ◆ Changing the pressure doesn't affect the amount of solid or liquid that dissolves
- ◆ They are incompressible.
- ◆ It does affect gases.

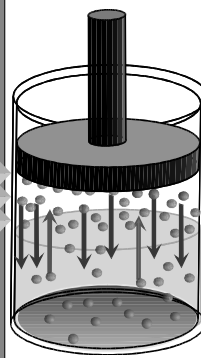
### Dissolving Gases



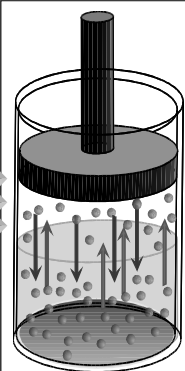
- ◆ Pressure affects the amount of gas that can dissolve in a liquid.
- ◆ The dissolved gas is at equilibrium with the gas above the liquid.



- ◆ The gas is at equilibrium with the dissolved gas in this solution.
- ◆ The equilibrium is dynamic.



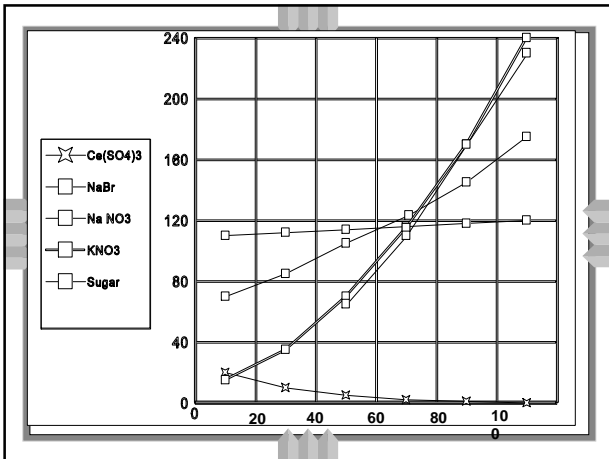
- ◆ If you increase the pressure the gas molecules dissolve faster.
- ◆ The equilibrium is disturbed.



- ◆ The system reaches a new equilibrium with more gas dissolved.
- ◆ Henry's Law.  
 $P = kC$   
Pressure = constant x Concentration of gas
- ◆ The stronger the attraction of the two, the higher the constant.


### Temperature Effects

- ◆ Increased temperature increases the rate at which a solid dissolves.
- ◆ We can't predict whether it will increase the amount of solid that dissolves.
- ◆ We must read it from a graph of experimental data.



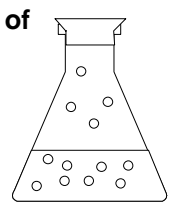
### Gases are predictable

- ◆ As temperature increases, solubility decreases.
- ◆ Gas molecules can move fast enough to escape.
- ◆ Thermal pollution.



### Vapor Pressure of Solutions

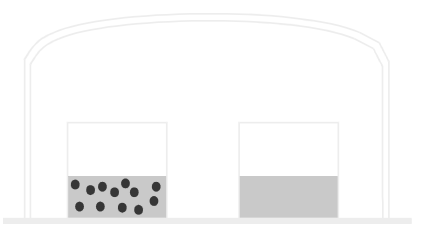
- ◆ A nonvolatile solvent lowers the vapor pressure of the solution.
- ◆ The molecules of the solvent must overcome the force of both the other solvent molecules and the solute molecules.



### Raoult's Law:

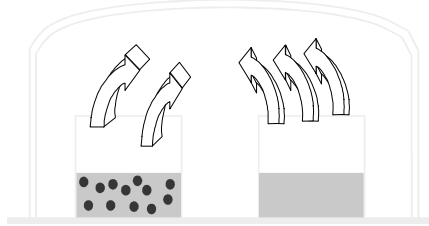
- ◆  $P_{\text{soln}} = \chi_{\text{solvent}} \times P_{\text{solvent}}$
- ◆ Vapor pressure of the solution = mole fraction of solvent x vapor pressure of the pure solvent
- ◆ Applies only to an ideal solution where the solute doesn't contribute to the vapor pressure.

- ◆ Water has a higher vapor pressure than a solution



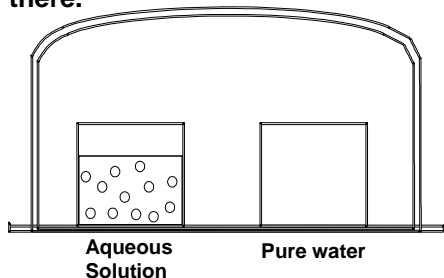
Aqueous Solution      Pure water

- ◆ Water evaporates faster from pure water than solution



Aqueous Solution      Pure water

- ◆ The water condenses faster in the solution so it should all end up there.



### Practice Problem

- ◆ A solution of cyclopentane with a nonvolatile compound has vapor pressure of 211 torr. If vapor pressure of the pure liquid is 313 torr, what is the mole fraction of the cyclopentane?

### Please enter your answer

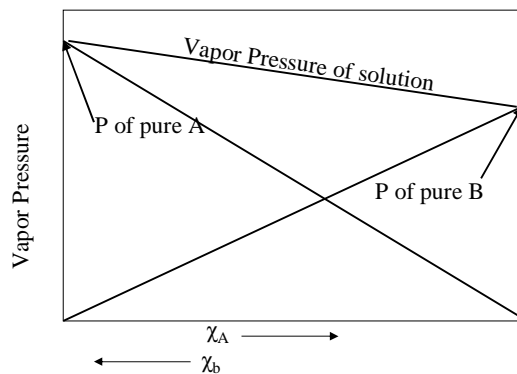
- ◆ Determine the vapor pressure of a solution at 25° C that has 45 grams of  $C_6H_{12}O_6$ , glucose, dissolved in 72 grams of  $H_2O$ . The vapor pressure of pure water at 25° C is 23.8 torr.

### Practice Question

- ◆ What is the composition of a pentane-hexane solution that has a vapor pressure of 350 torr at 25°C ?
- ◆ The vapor pressures at 25°C are
  - pentane 511 torr
  - hexane 150 torr.
- ◆ What is the composition of the vapor?

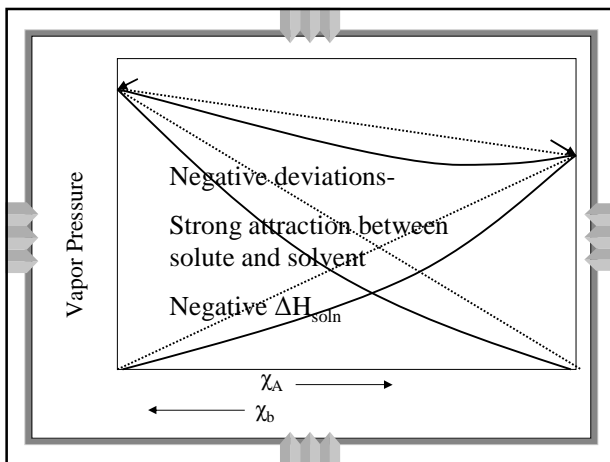
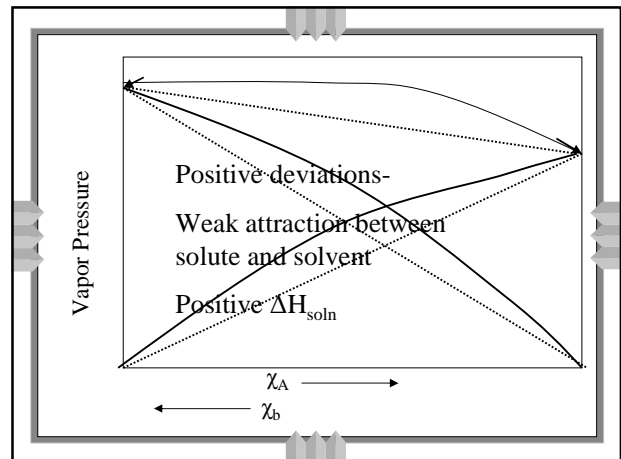
### Ideal solutions

- ◆ Liquid-liquid solutions where both are volatile.
- ◆ Modify Raoult's Law to
  - ◆  $P_{total} = P_A + P_B = \chi_A P_A^0 + \chi_B P_B^0$
  - ◆  $P_{total}$  = vapor pressure of mixture
  - ◆  $P_A^0$  = vapor pressure of pure A
  - ◆ If this equation works then the solution is ideal.



## Deviations

- ◆ If solvent has a strong affinity for solute (H bonding).
- ◆ Lowers solvent's ability to escape.
- ◆ Lower vapor pressure than expected.
- ◆ Negative deviation from Raoult's law.
- ◆  $\Delta H_{\text{soln}}$  is large and negative exothermic.
- ◆ Endothermic  $\Delta H_{\text{soln}}$  indicates positive deviation.



## Colligative Properties

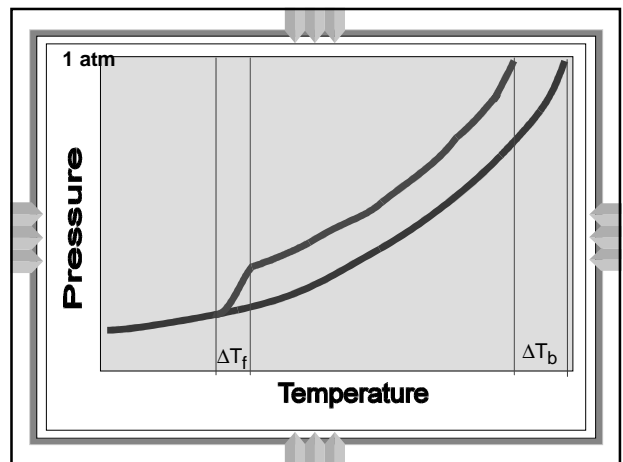
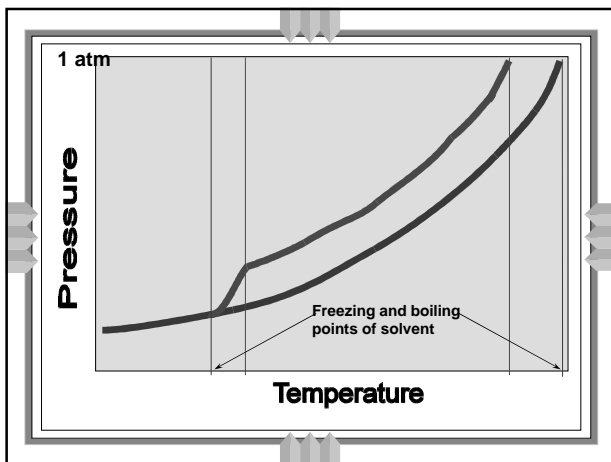
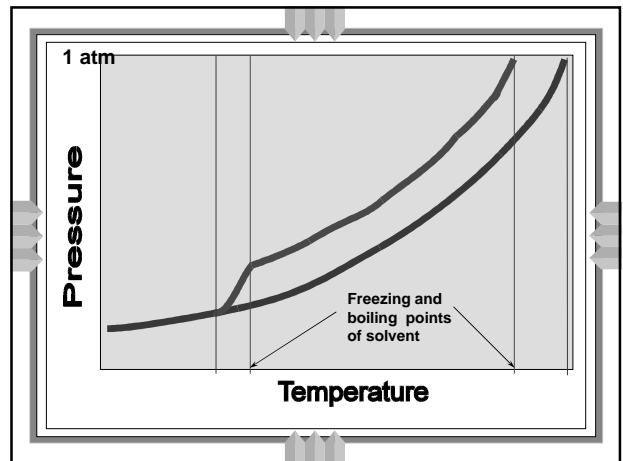
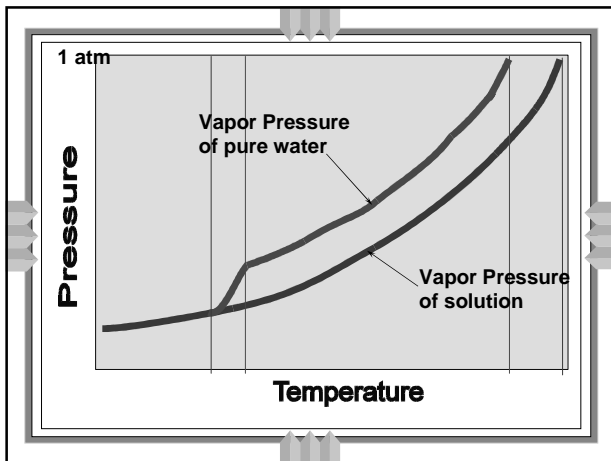
- ◆ Because dissolved particles affect vapor pressure - they affect phase changes.
- ◆ Colligative properties depend only on the number - not the kind of solute particles present
- ◆ Useful for determining molar mass

## Boiling point Elevation

- ◆ Because a non-volatile solute lowers the vapor pressure it raises the boiling point.
- ◆ The equation is:  $\Delta T = K_b m_{\text{solute}}$
- ◆  $\Delta T$  is the change in the boiling point
- ◆  $K_b$  is a constant determined by the solvent.
- ◆  $m_{\text{solute}}$  is the molality of the solute

## Freezing point Depression

- ◆ Because a non-volatile solute lowers the vapor pressure of the solution it lowers the freezing point.
- ◆ The equation is:  $\Delta T = -K_f m_{\text{solute}}$
- ◆  $\Delta T$  is the change in the freezing point
- ◆  $K_f$  is a constant determined by the solvent
- ◆  $m_{\text{solute}}$  is the molality of the solute



### Electrolytes in solution

- ◆ Since colligative properties only depend on the number of molecules.
- ◆ Ionic compounds should have a bigger effect.
- ◆ When they dissolve they dissociate.
- ◆ Individual Na and Cl ions fall apart.
- ◆ 1 mole of NaCl makes 2 moles of ions.
- ◆ 1 mole  $\text{Al}(\text{NO}_3)_3$  makes 4 moles ions.

- ◆ Electrolytes have a bigger impact on on melting and freezing points per mole because they make more pieces.
- ◆ Relationship is expressed using the van't Hoff factor  $i$ 

$$i = \frac{\text{Moles of particles in solution}}{\text{Moles of solute dissolved}}$$
- ◆ The expected value can be determined from the formula of the compound.



- ◆ The actual value is usually less because
- ◆ At any given instant some of the ions in solution will be paired up.
- ◆ Ion pairing increases with concentration.
- ◆  $i$  decreases with increasing concentration.
- ◆ We can change our formulas to

$$\Delta T = iK_m$$

## LAB

- ◆ **Purpose:** to experimentally determine the van't Hoff factor for sodium chloride
- ◆ **Materials and equipment**
  - Sodium chloride                      Water
  - Food coloring
  - Beakers                                      Thermometer
  - Graduated cylinder                      Ice cube tray
  - Foam cup

## Lab

- ◆ 1. Make approximately 0.50 m , 1.0 m, and 1.5 m NaCl solutions
- ◆ 2. Add a different color of food coloring for each
- ◆ 3. Put in labeled ice tray
- ◆ 4. Freeze overnight
- ◆ 5. Melt the ice cubes in their own solutions and determine the freezing point depression

## Lab

- ◆ **Calculations**
- ◆ 1. Determine the van't Hoff factor for sodium chloride in each solution.
- ◆ **Error analysis and conclusion**