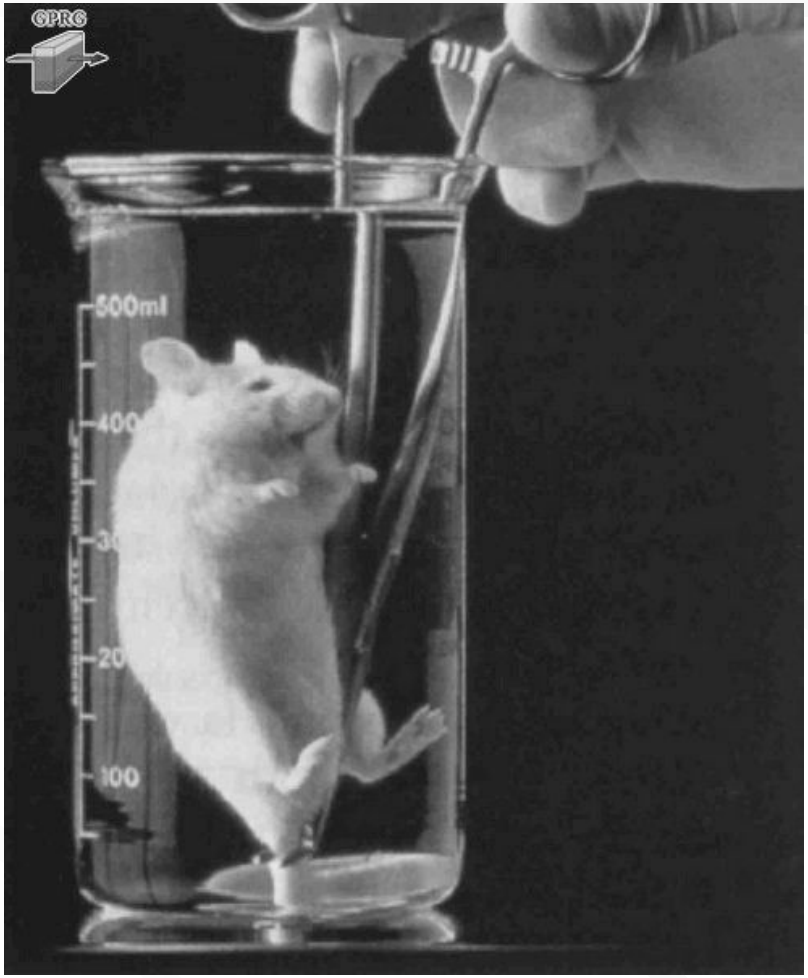
# *Professor K*

Solutions

# *More on solutions*

- Earlier, we explored general terminology and reactions of solutions.
- We now return back to solutions to explain some physical phenomena, such as why impure water (a solution of ethylene glycol, aka antifreeze) is used as a car coolant instead of just pure water.
- Solutions can be of several types: gas-gas, gas-liquid, liquid-liquid, solid-liquid, gas-solid, solid-solid (and, for completeness, one would suppose, combinations with the other 2 phases of matter as well)
- How can the compound the mouse is breathing be fluorine-containing when F is a highly toxic cumulative bone-marrow attacker?

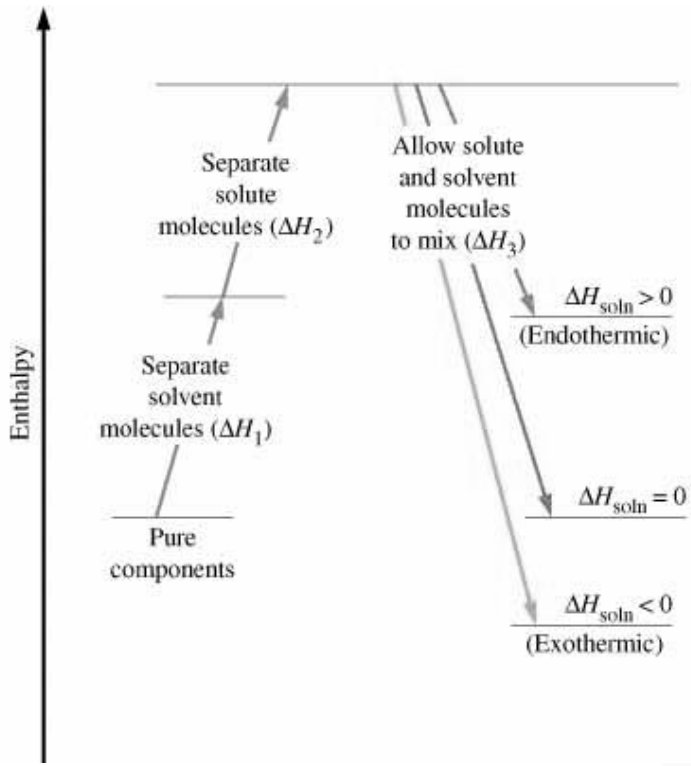


# *Molarity revisited*

- For mass percent, volume percent, mole percent or mole fraction, ppm and ppb calculations, DON'T FORGET THE UNITS!
- ppm = mg/L
- ppb = ug/L
- ppt = ng/L
- Analysis of low concentrations can be challenging…
- Femtomolar ($10^{-15}$) analysis IS possible, luckily, since sometimes compounds are toxic at ppq levels!! (e.g.- dioxin)

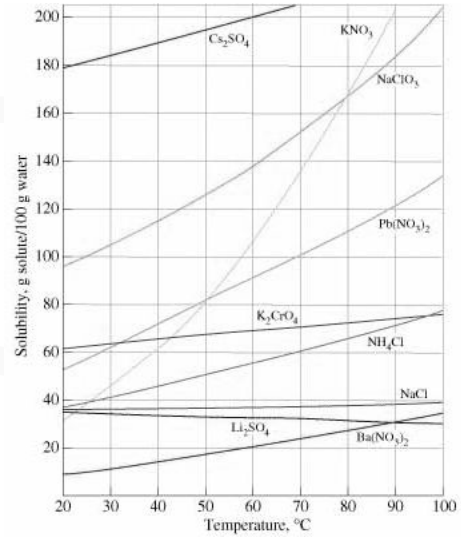
# *Dissolution*

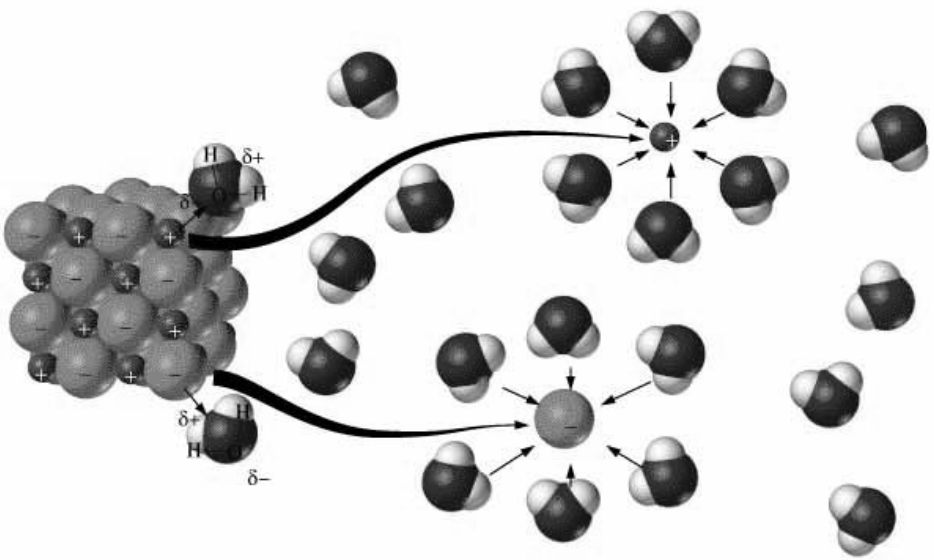
- Can be endothermic or exothermic
  - "cold packs" ($NH_4NO_3$) (what else is this used for?)
  - "hot packs" ($MgSO_4$)
- Enthalpy of solution (below)
- Nonideal solutions can expand or contract upon dissolution.....why??
- Thus, M is T dependent.

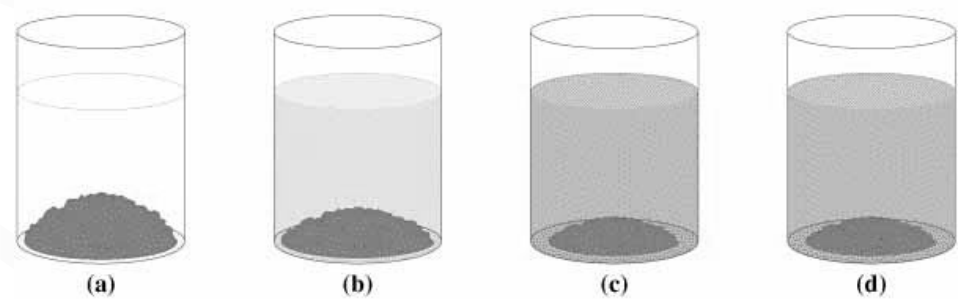


# *Why do things dissolve?*

- LIKE DISSOLVES LIKE
- Fully dissolving compounds are said to be MISCIBLE
- Saturated solution- dynamic equilibrium
- Solubility vs. temperature- supersaturation
- Purification by supersaturation



# *Solubility rules (again!)*

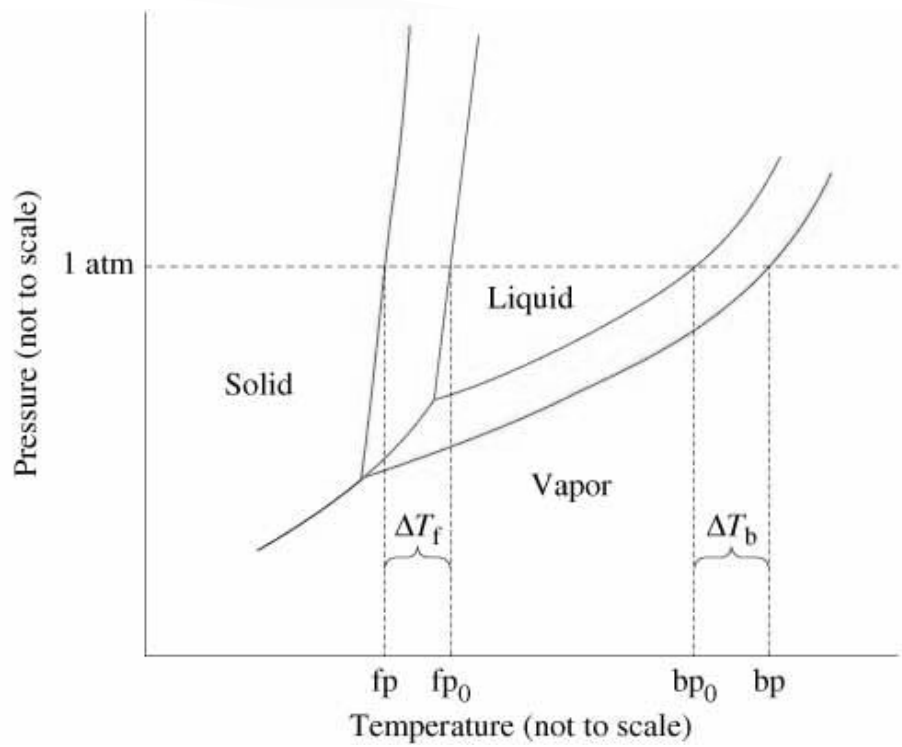
- Group I cation and $NH^{4+}$ salts are soluble (some $Li^{+}$ exceptions)
- Nitrates, acetates, perchlorates are soluble
- Chlorides, bromides, iodides are soluble
- Sulfates are soluble except for Ca, Sr, Ba.
- Ag, Pb, Hg(I) salts are insoluble
- Carbonates, phosphates, sulfides, oxides, and hydroxides are insoluble (sulfides of Group II cations and hydroxides of $Ca^{2+}$, $Sr^{2+}$ and $Ba^{2+}$ are slightly soluble)

# *Gas solubility*

- Temperature dependence
  - No general rule though most gases are less soluble in water at higher temperature
- Pressure dependence
  - Higher pressure = higher solubility due to equilibrium = Henry's Law (1803)... very common example?

# *Colligative properties*

- Depend on the number of solute particles present, NOT their identity
- Vapor pressure- lowered by presence of solute
  - Raoult's Law- $P_{solv} = x_{solv} P^o_{solv}$
  - Important application in fractional distillation.
  - Used in chemical purification, oil refining, ethanol production, etc.
- Freezing point depression $\Delta T = K_f m$ (m = moles solute / kg solvent)
- Boiling point elevation $\Delta T = K_b m$

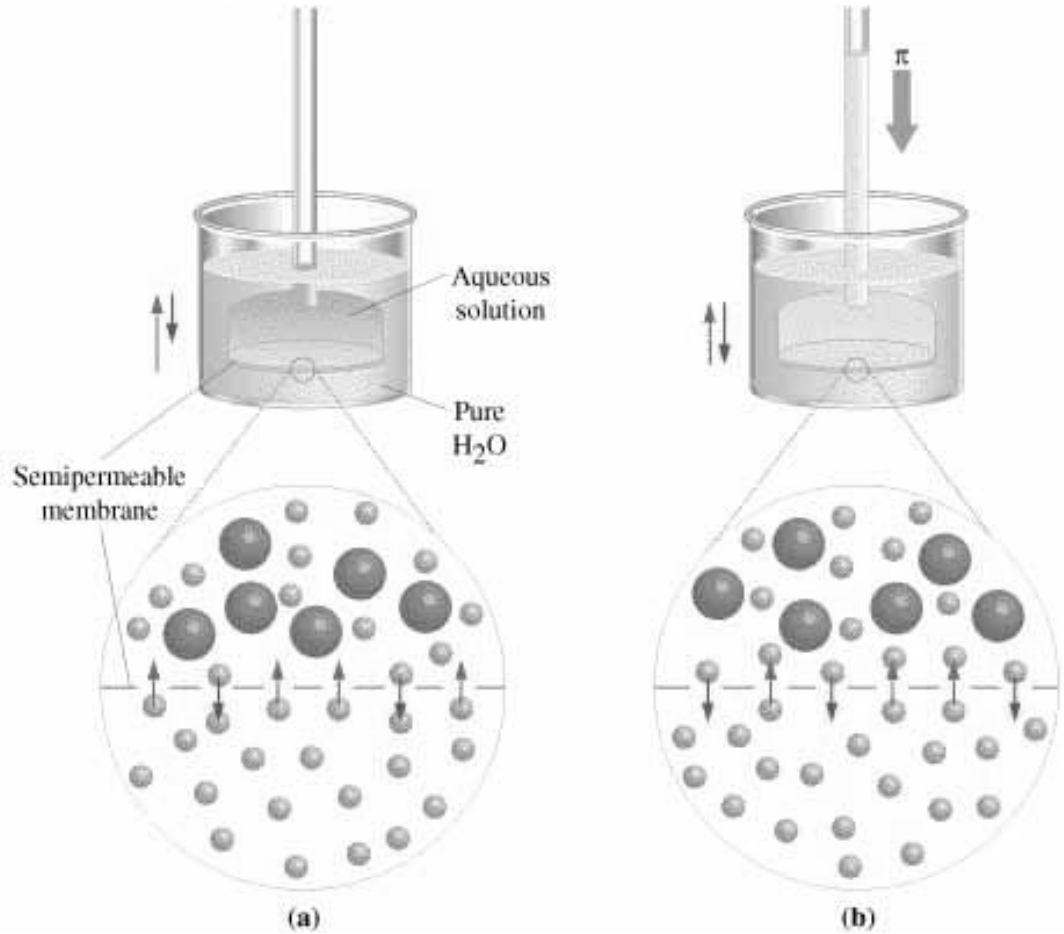


# *Osmotic pressure*

- OSMOSIS is the net flow of solvent molecules from pure solvent through a semi permeable membrane (small solvent molecules may pass through, but not large solute molecules) into a solution.
- For a 20% sucrose solution, osmosis can lift the solution 150m!
- ie- dilution of a solution by solvent through a barrier
- Can reduce solvent flow into solution by increasing flow of solvent out of the solution by applying pressure to it.
- At the OSMOTIC PRESSURE, osmosis ceases.
- (About 15 atm for the 20% sugar solution.)

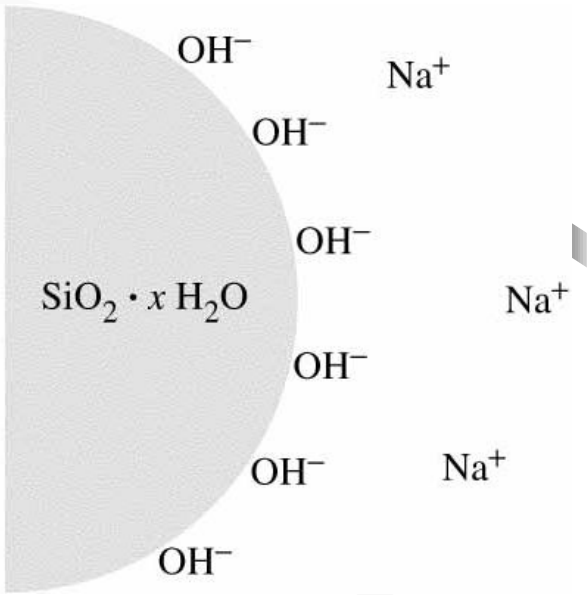
# *Osmotic pressure (cont'd)*

- $\pi$ = MRT
- (yes, molarity even though it's a colligative property)



# *Colloids*

- Between a solution and a suspension
- Based on particle size (1-1000nm)
- Too small to see with regular microscope or settle out (can often COAGULATE-PRECIPITATE with an electrolyte)
- Large enough to diffract light (Tyndall effect)
- A SOL is a solid in a liquid
- An EMULSION is a liquid in a liquid
- An AEROSOL is a solid or liquid in a gas



# *What I want you to know about solutions and kinetics (preview)*

- Solutions can incorporate the various states of matter.
- Definitions of, calculations with molarity and molality, including ppm, ppb, ppt.
- Solutions can expand or contract upon dissolution, thus M is T dependent.
- Dissolution can be exo- or endothermic.
- Like dissolves like.
- Colligative properties- specifically boiling point elevation and freezing point depression.

# *What I want you to know about solutions and kinetics (cont'd)*

- Rate constants (little k) will be discussed in P.Chem and are experimentally determined.
- Reaction rate is how fast a reaction occurs.
- At eq., forward and reverse rates are equal.
- Reactant and product concentrations are constant at equilibrium, even though it is DYNAMIC.
- Product concentrations divided by reactant concentrations gives the eq. constant expression or equation (big K), with exponents equal to the stoichiometric coefficients from the balanced equation (pure solids and liquids do not appear).
- Size of K (either in terms of concentration or pressure) gives the extent of reaction ("how far to the left or right the reaction lies").
- The reaction quotient Q starts at zero and goes to K.
- Use LeChatelier to predict effects of changing P, V or T
- Catalysts (enzymes, biologically) lower activation energy and speed up reactions… they do not effect eq.