Solution Chemistry Notes

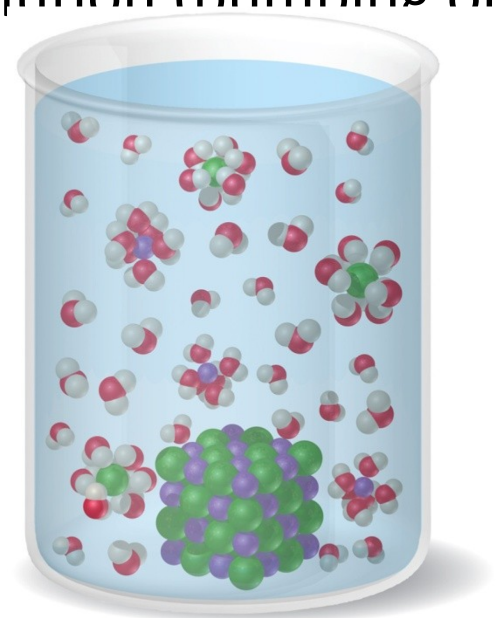
Solutions

- Basic definitions
  - Solution: homogenous mixture
  - Solute: substance that is dissolved
  - Solvent: substance that contains the solute in a solution
- Process of Dissolving:
  - Molecules of the solvent "pull apart" the solute molecules, and distributes them within the solvent
- How to tell the solute from the solvent
  - The substance that is in the greater amount is the solvent
  - The substance that keeps its phase is the solvent

Types of Solutions

State of Solution	State of Solvent	State of Solute	Example
Gas	Gas	Gas	Air
Liquid	Liquid	Gas	Oxygen in water
Liquid	Liquid	Liquid	Alcohol in water
Liquid	Liquid	Solid	Salt in water
Solid	Solid	Gas	Hydrogen in palladium
Solid	Solid	Liquid	Mercury in silver
Solid	Solid	Solid	Silver in gold

- Saturated solutions are at dynamic equilibrium – the solute is dissolving and crystallizing at an equal rate.
- The solubility of a chemical determines how much can be dissolved. Some chemicals are highly soluble (much can dissolve), some are not soluble (cannot be dissolved at all).
- Supersaturate solutions hold more solute than the typical solubility allows. These solutions can crystallize easily, by adding a seed crystal or even by simply disturbing the solution (bumping or shaking).



Water molecules are pulling apart the positive (Na^+) and negative (Cl^-) ions in the table salt.

What can dissolve??

- In order for a solute to dissolve, it must have similar intermolecular forces
- Water is polar (has a positive and negative charge) so it can dissolve polar and ionic compounds.
  - Salt (NaCl) is ionic, the positive and negative ions dissolve in water
  - Sugar ($C_{12}H_{22}O_{11}$) is polar, so water will dissolve it.
  - Oil is non-polar, and the molecules are extremely large. This is why oil cannot dissolve in water.
- “Like dissolves Like”

Dissolution in Water

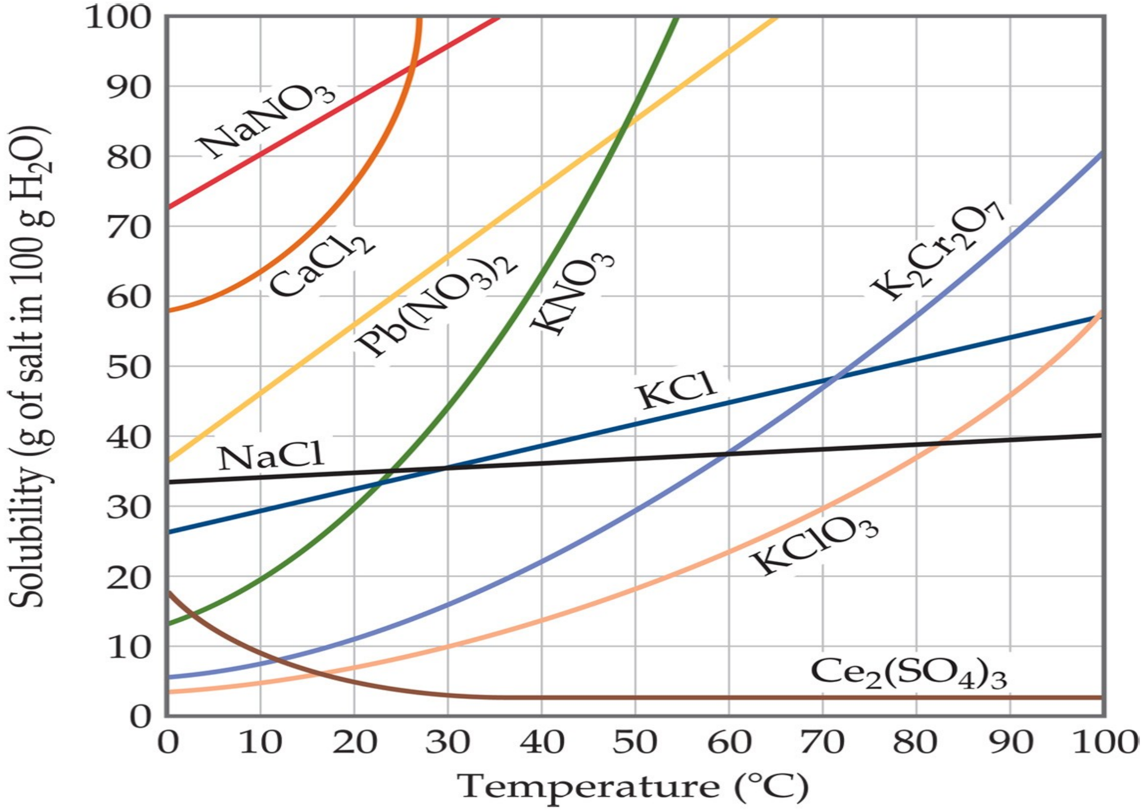
- When an ionic solid is placed in water, the water pulls the solid apart into its individual ions
- Below is the dissolution of sodium chloride reaction:
    - $NaCl_{(s)} \rightarrow Na^{+}_{(aq)} + Cl^{-}_{(aq)}$

How to Increase Solubility

- You can dissolve more of a solute in a set amount of solvent by doing the following:
  - 1. increase the temperature – the space between the solvent particles expands, allowing more room for more solute
  - 2. Increase pressure (for gases only) – this forces the solute into the solvent
  - 3. Nature of solute – some chemicals cannot dissolve under any circumstances. You may need to find a different solute

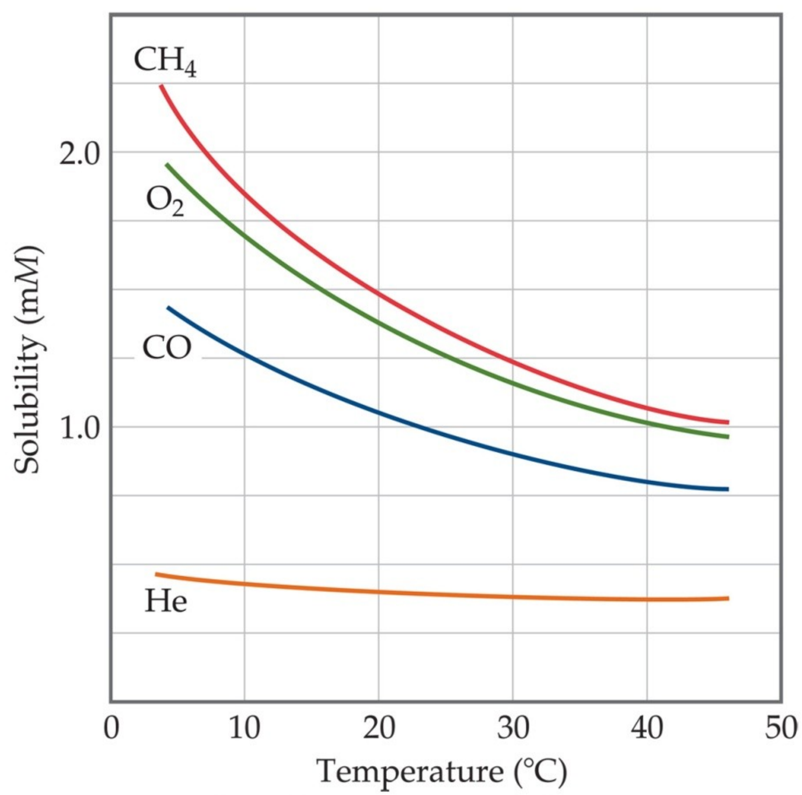
Solubility of Some Solids

- The chart below shows how solubility of some compounds change with time
- What solutes actually decrease in solubility with an increase in temperature?



Solubility of Gases

This graph shows how gases decrease in solubility as temperature increases



How to Increase the Rate of Dissolving

- In order to speed up the solute mixing with the solvent, you can do the following:
  - Stir/shake the mixture of course this doesn’t work for gases
  - Heat the mixture

Calculating Concentration

- General Terms
  - Concentrated – much solute dissolved in solvent
  - Dilute – very little solute dissolved in solvent
- More specific
  - Molarity – moles of solute per Liter of solution
  - Molality – moles of solute per kilogram of solvent
  - Mole fraction – moles of component per moles of all components

Concentrations

$$Molarity = \frac{moles\ solute}{L\ solution} = M$$

$$Molality = \frac{moles\ solute}{Kg\ solvent} = m$$

$$Mole\ Fraction = \frac{moles\ component}{total\ moles} = x$$

What is the molarity of 450.5g of silver nitrate ($AgNO_3$) dissolved in 675mL of Water?

$$first\ \ find\ the\ moles$$

$$\frac{450.5g\ AgNO_3}{1}\ x\ \frac{1mole\ AgNO_3}{169.88g\ AgNO_3} = 2.65187191 moles\ AgNO_3$$

$$Molarity = \frac{moles\ solute}{L\ solution} = \frac{2.65187\ moles}{.675\ L} = 3.928696M \approx 3.929M$$

- How many grams of sodium chloride is needed to make 34.2 mL of a 0.87 M solution?

$$\frac{34.2\,mL}{1}\,x\,\frac{1\,L}{1000\,mL}\,x\,\frac{.87\,moles}{1\,L}\,x\,\frac{58.44\,g}{mole}=1.73882376\approx 1.7\,g\;NaCL$$

- 50.0 grams of sugar ($C_{12}H_{22}O_{11}$) is mixed with 365.0 mL of water. Calculate the molality and mole fraction of sugar.

$$\frac{50.0\,g\ sugar}{1}\,x\,\frac{1\,mol}{342.34\,g}=.14605\,mol\ sugar$$

$$\frac{365\,g\ H_2O}{1}\,x\,\frac{1\,mol}{18.02\,g}=20.255\,mol\ H_2O$$

$$m=\frac{moles\ solute}{kg\ solvent}=\frac{.14605\,mol}{.365kg}=.400m$$

$$x=\frac{moles\ solute}{total\ moles}=\frac{.14605\,moles}{(20.255+.14605)\,moles}=0.007158787\approx 0.00716$$

- You have a 20% by mass salt water solution (NaCl) with a density of 1.04 g/ml. Find the molarity, molality, and mole fraction.

$$\%\,mass = \frac{mass\ solute}{mass\ solution} x100 \ \Rightarrow\ 20\% = \frac{20g\ NaCl}{100g\ solution} x100$$

$$\frac{20.0g\ NaCl}{1} x \frac{1\,mol}{58.44g} = .34223\,mol\ NaCl$$

$$\frac{100g\ solution}{1} x \frac{1\,mL}{1.04g} = 96.15\,mL\ solution$$

$$M = \frac{moles\ solute}{L\ solution} = \frac{.34223\,mol}{.09615\,L} = 3.5593 \approx 3.56M$$

$$m = \frac{moles\ solute}{kg\ solvent} = \frac{0.34223\,mol}{0.080\,Kg} = 4.277875 \approx 4.28m$$

$$x = \frac{.34223}{(.34223 + 4.4395)} = 0.0716$$

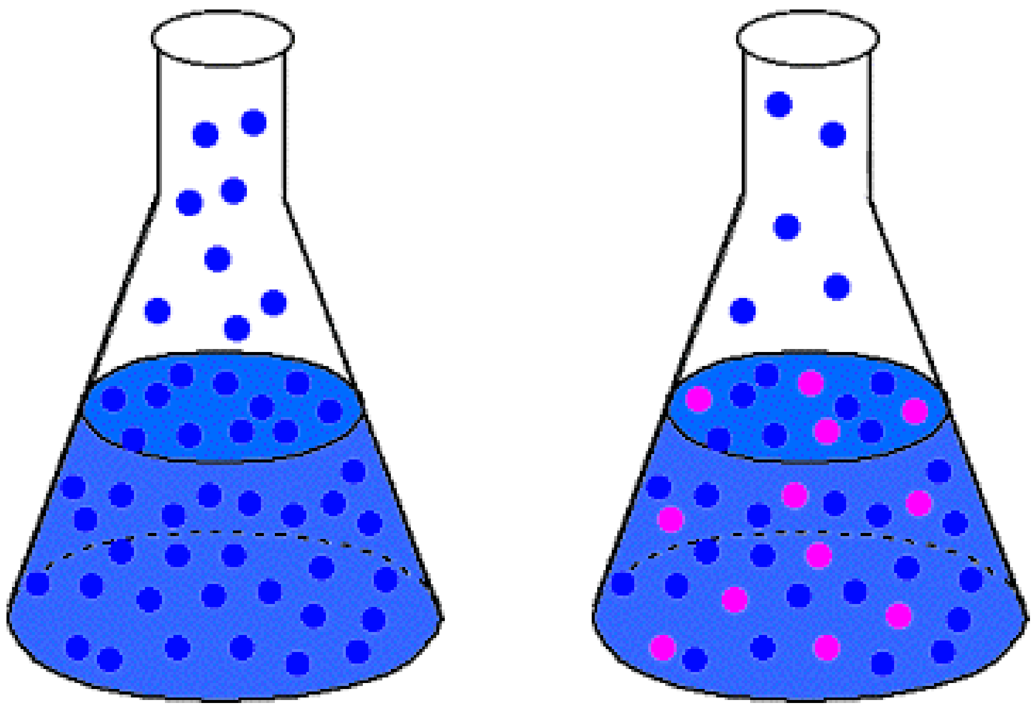
Colligative Properties

- Colligative properties are properties of a solvent that are affected by the amount of solute dissolved.
- There are three types of colligative properties
  - Vapor pressure lowering
  - Freezing point depression
  - Boiling point elevation
- The greater the amount of solute, the greater the change in these properties

Vapor Pressure Lowering

- Remember: Vapor pressure is caused by the tiny gas particles floating above a liquid
- When a solute is mixed, the solvent molecules are holding onto the solute, so they cannot escape into the gas phase

Pure solvent



Solute molecules (red) are holding solvent molecules in liquid phase

- To Calculate Vapor Pressure Lowering
- $P_a = X_a P_a^\circ$
  - P_a° = vapor pressure of pure solvent
  - Xa = Mole fraction of solvent
  - P_a = vapor pressure of solution

Ex.: The vapor pressure of pure water at 22.0°C is 21 Torr. Calculate the new vapor pressure of 245g of water mixed with 45.2 g of ethyl alcohol (C_2H_5OH)

Freezing Point Lowering

- When a solute is added to a solvent, the freezing point of the solution is lower than that of the pure solvent.

- Equation for freezing point depression:
  - $\Delta T_f = K_f \bullet m$
    - ΔT_f = change in freezing point
    - K_f = freezing point constant
    - m = molality of the solution

- Calculate the new freezing point of 655 mL of water with 150.0g of sugar ($C_{12}H_{22}O_{11}$) dissolved. The K_f for water is 1.86°C/m

$$first\ find\ molality$$

$$m=\frac{moles\ solute}{kg\ solvent}=\frac{\left(\frac{150.0g\ sugar}{1}x\frac{1mol}{342.34\ g}\right)}{\left(\frac{655\ mL\ H_2O}{1}x\frac{1g}{1mL}x\frac{1Kg}{1000g}\right)}=0.6689\approx 0.669m$$

$$\Delta T_f=K_f\bullet m=\frac{1.86^{\circ}C}{m}x\frac{0.6689m}{1}=1.244\approx 1.24$$

$$0.00-1.24=-1.24^{\circ}C$$

Boiling Point Elevation

- When a solute is added to a solvent, the boiling point of the solution is higher than that of the pure solvent
- Equation for boiling point elevation
  - $\Delta T_b = K_b \bullet m$
    - ΔT_b = change in boiling point
    - K_b = boiling point constant
    - M = molality of the solution

Calculating Molar Mass

- The molar mass of an unknown chemical can be calculated by knowing how much it lowers the freezing point of a solvent.
- Ex: 18.2g of an unknown compound is dissolved in 995 mL of water. The compound lowers the freezing point by 0.194°C. Calculate the molar mass of this compound. (K_f for water is 1.86 °C/m)