13.1 – The Solution Process

Interactions between solute and solvent molecules is solvation (with water it’s hydration)

Three Steps:

1) Solute particles separate from one another (endothermic)
2) Solvent particles separate from one another (endothermic)
3) Solute and solvent particles mix (exothermic)

\[ \Delta H_{\text{soln}} = \Delta H_{\text{solute}} + \Delta H_{\text{solvent}} + \Delta H_{\text{mix}} \]

Solution process usually increases entropy

Mixing of two non-polar liquids is spontaneous and thermoneutral (entropy is driving force)

Ionic solids with ions of multiple charge \((\geq +2)\) produce heat upon dissolution (exothermic enthalpy is driving force and entropy decreases because of strong binding and ordering of water with charged cation)

Entropy increases for ions of +/- 1 charge

Note: A drop in temperature of a solution means the reaction was endothermic. An increase in the temperature of the solution means the reaction was exothermic.

13.2 – Saturated Solutions and Solubility

Crystallization – Opposite of the solution process

To create a super saturated solution, the solution can be prepared at a high temperature and slowly cooled

A seed crystal addition will lead to crystallization of the solution

Metals below hydrogen only dissolve in HNO₃ or HNO₃ + HCl

Evaporation of aqueous solutions of many ionic compounds (especially with multiple charged ions) will give solids that retain some water molecules to become crystal hydrates

Water molecules are bound by ion-dipole attractions

Organic compounds are only soluble with significant hydrogen bonding

Hydrocarbons and haloalkanes are insoluble

Alcohols and carboxylic acids with 4 carbons or less are soluble

Molecules with multiple H-bond forming groups are soluble

13.3 – Factors Affecting Solubility

The stronger the attractions between solute and solvent, the greater the solubility of the solute in the solvent

Solubility of solid solutes in liquid solvents increases with increases temperature but is opposite for gases in liquid (no rule for liquids in liquids)

Solubility of gas is directly proportional to partial pressure of gas (not applicable for liquids and solids)

Henry’s Law: \( S_g = kP_g \)
13.4 – Expressing Solution Concentration

Mass% = \frac{\text{Mass of substance}}{\text{Total mass}} \times 100

Ppm = \frac{\text{Mass of substance}}{\text{Total mass}} \times 10^6

Ppb = \frac{\text{Mass of substance}}{\text{Total mass}} \times 10^9

Mole Fraction = \frac{\text{Moles of substance}}{\text{Total moles}}

Molarity = \frac{\text{Mol solute}}{\text{L soln}}

Molarity can change with temperature due to volume

Make sure it is liters of solution

Molality = \frac{\text{Mol solute}}{\text{kg solvent}}

Molality is dependent of temperature

If a crystal hydrate is dissolved in water, note that the water from the hydrate also becomes part of the solvent

Normality = \frac{\text{Mol reactive H}^+ \text{ or O}H^-}{\text{L soln}}

(Essentially, the number of reactive, dissociated species times the molarity)

13.5 – Colligative Properties

Colligative Properties – Depends on the number of particles present not on the identity

If a non-volatile solute is dissolved in a volatile solvent, the vapor pressure of the solvent decreases, and there is a lower [ ] of solvent in both the liquid and gas

Raoult’s Law: \( P_{\text{soln}} = P_{\text{solv}} \times \chi_{\text{solv}} \)

NOTE: To get the correct mole fraction, analyze the solute! If it’s an electrolyte, make sure to always use the moles of TOTAL NUMBER OF MOLES OF PARTICLES IN SOLUTION

The mole fraction of the vapor is equivalent to the partial pressure of the vapor: \( \chi_{A(\text{Vap})} = \frac{P_A}{P_{\text{Total}}} \)

Since vapor pressure of solvent is less with solute particles added and vapor pressure needs to equal atmospheric pressure, there is a boiling point elevation because more temperature is needed

There is a freezing point depression for solutions with solute particles because freezing always forms pure solid solvent, so it requires more “frost” to freeze 95% pure water, for instance, than 100% pure water

Since melting point and freezing point are the same, adding solute will make something easier to melt as long as it’s soluble

\[ \Delta T_b = K_p \times m \times i \quad \Delta T_f = K_f \times m \times i \]

where molality is for all particles of solute and \( \Delta T_b \) is added to the normal point and \( \Delta T_f \) is subtracted (constants are only for solvent)

Because electrolytes dissociate into ions, NaCl (for instance) shows about twice the \( \Delta T_f \) than a non electrolyte

0.10 \text{ mol NaCl} = 0.20 \text{ mol ions}
Andrew Rosen

Ion Pairs – When dissociated ions, for a period of time, group together to form a pair

Makes dissociation considered incomplete, especially at high concentrations (dissociation is less likely in high concentrations of the electrolyte and more likely in dilute solutions)

Van’t Hoff Factor \((i)\) – Average number of particles produced in solution from 1 mol of an electrolyte

Can be anywhere between 1 to the total number of ions in the formula unit

Osmotic Pressure – Pressure required to stop osmosis \((P = dgh)\) in the column equals \(\pi\), osmotic pressure

\[
\pi = \frac{nRT}{V} = MRTi
\]

Deviates from ideal solution (ideal Raoult solution) when the solute-solvent interactions are exceptionally strong (lower vapor pressure than expected)

At higher concentrations the vant hoff factor is lower because there is more ion pairing

**Chapter 13.6 – Colloids**

Common (true) solutions have solute particles that are small, so there is minimal light scattering

Colloids solutions have larger particles made of small insoluble substances and disperse light for a milky appearance

Different response to light is the Tyndall effect

Air contains enough dust to display Tyndall effect, want the violet end of the spectrum has more color scattering than red

Particles in stable colloid solutions must not cling to each other, so more ions of the same or similar charge on the surface prevent this

For the colloid to be useful, it needs to be aqueous and thus polar and hydrophilic

Hydrophobic colloids are made of nonpolar organic substances or *metallic nanoparticles*

Metallic nanoparticles can be stabilized due to adherence to the surface of ions

Surfactant = Amphiphilic Molecule (both-loving)

Can stabilize nonpolar oil in water due to the tail and head of the stearate ion

This is how bar soap works (sodium stearate)

Heating a colloidal solution can lead to coagulation or adding an electrolyte since it will neutralize the surface charges