

1 Solutions

Where can you find the answers to solubility problems? In the solutions manual.

1.1 Solutions, Colloids, Suspensions, Electrolytes & Solubility

- Mixtures that are mostly liquid can be classified as one of three different things -
 - Solutions (homogeneous mixtures)
 - Same makeup throughout - evenly mixes on the molecular level
- Heterogeneous Mixtures
 - Different makeup in different parts of the mixture.
 - Includes colloids and suspensions.
- Simple tests can help determine what type of mixture you have.

Solutions are made up of two parts -

- Solute
- Solvent

The solute dissolves into the solvent.

Properties of solutions:

- Clear, but not necessarily colorless.
- Solute particles are ions or molecules with a size less than a nanometer - very small.
- Particles cannot be seen even with a microscope, and the mixture doesn't scatter light.
- Cannot be separated by filtering, settling, or centrifuging.
- Solutions can be separated by evaporation.
- Can conduct electricity if an ionic compound is dissolved. Do not conduct if covalent/molecular compounds are dissolved.

Colloids:

- A heterogeneous mixture. Some can appear homogeneous with just your eyes, but the particles dispersed throughout the liquid can be seen with a microscope.
- The particles in a colloid are bigger than the particles dispersed in a solution.
- Can appear clear, slightly cloudy, or very cloudy.
- They scatter light. This is called the Tyndall Effect.
- Dispersed particles are about 10-100 times bigger than the particles dissolved in solutions.
- Will not conduct electricity.
- Will not separate into separate parts by settling, standing, or filtering.
- Can be separated by centrifuge or heating, depends on the specific colloid.

Suspensions:

- Large particles dispersed in liquid - can be seen with a light microscope and sometimes the naked eye.
- Cloudy when shaken, but the dispersed particles settle upon standing.

- Can speed separation by filtering or centrifuging.
- Will not conduct electricity.

Exercise A mixture doesn't leave residue on paper. Identify what this is.

The solvent is what is doing the dissolving. It is usually water because it is a non-ionic polar molecule that can dissolve anything else that is non-ionic or polar. Water can also dissolve most ionic compounds due to its hydrogen bonding.

The solute is what is dissolved in something else.

Electrolytes:

- Some solutions can conduct electricity. These are called electrolytes.
- Either ionic compounds or strong acids can act like electrolytes.
- Dissociated ions carry an electric current.

There are three categories of strong electrolytes: strong acids, strong bases, and soluble salts.

The strong acids are - HCl, HBr, HI, H₂SO₄, HNO₃, HClO₃, and HClO₄.

Strong bases are hydroxides of group I and heavy group II metals (Ca, Sr, Ba)

The soluble salts are compounds with ions of NO₃⁻, Group I, NH₄⁺, C₂H₃O₂⁻, ClO₄⁻, ClO₃⁻ with no exceptions. Cl⁻, Br⁻ and I⁻ are soluble except with Pb⁺², Ag⁺, and Hg₂⁺². SO₄⁻² is soluble except with Pb⁺², Ag⁺, Hg₂⁺², Ca⁺², Sr⁺², and Ba⁺².

Solubility Factors:

First we need to know if something will dissolve.

- Miscible - two substances that are miscible are soluble together and will mix.
- Immiscible - two insoluble liquids; they will not mix together.
- Polar things will dissolve in other polar things.
- Ionic substances will dissolve in water if the ionic bonds aren't too strong.
- Polar and Nonpolar substances will not dissolve together.

The process of dissolving: Solvation

1. Solvent is attracted to the solute.
2. Solvent particles surround the solute particles and pull them into solution.

Factors affecting rate of solution:

- Surface area - more contact between solute and solvent increases rate of solution.
- Agitation - mixing the mixture causes more contact between solute & solvent, increases rate of solution.
- Temperature - solvent particles are moving faster at higher temperatures, increases rate of solution.

Sometimes substances will not fully mix together no matter how much work is done. It all has to do with IMFs. Similar IMFs will dissolve together.

Solubility is the amount of solute that will dissolve in a given amount of solvent.

The rules for this are different for solids and gases.

Temperature

- Higher temperatures make gases less soluble in liquid
- Most solids are more soluble in liquid

Pressure

- Higher pressure above a solution will increase the solubility of a gas. This relationship is known as Henry's Law

- have no effect on solid solubility

Solubility is a physical property and is the amount of a substance that can be dissolved in a liquid.

On a solubility graph, if the amount is on the line, it is called saturated.

Saturation of a solution is sort of like saturation of a sponge. There are only so many holes in a sponge to hold a liquid, and when it is full there is simply no more room.

A saturated solution is when no more solute can dissolve.

Unsaturated solution is when more solute could dissolve. Any point below the line is unsaturated.

Supersaturated is when more solute is dissolved than normally could be. Any disturbance or seed crystal will cause the excess to precipitate out. Supersaturated means you are above the line and all solute is dissolved. It's more likely that you actually have a saturated solution with some undissolved solute present.

1.2 Units of Concentration

A concentrated solution has a relatively high amount of solute.

A dilute solution has a relatively low amount of solute.

What concentration units are most useful in chemistry?

- Molarity = moles solute/liters solution
- Molality - moles solute/kg solvent
- % Mass = grams part/grams total $\times 100$
- Mole Fraction = moles part/moles total

Molarity

- The molarity of a solution is a measure of how many moles of the solute are present for each liter of solution.
- The liters of solution is not necessarily how much water was added. The final volume is usually more than the amount of pure water added since the solute adds to the volume.
- $M = \text{moles solute/Liters solution}$

Higher molarity values mean more concentrated.

Exercise How many grams of HCl would be necessary to create 2.00 L of a 4.0 M solution?

Molality is the concentration calculated by dividing the number of moles of solute by kilograms of solvent used to dissolve. This is useful for colligative properties - something we'll get to later.

$m = \text{mol solute/kg solvent}$

Exercise A solution contains 5.3 grams of carbon dioxide dissolved in 450. grams of water. What is the molality of the solution?

The molarity or molality of a solution does not tell you whether it is strong or weak. It tells you whether it is concentrated or dilute.

Mole fraction for one component of a solution is moles of component/total moles of all components. Mole fraction has no units.

Exercise You mix 30. grams of lithium chloride into 100.0 grams of water. What is the mole fraction of lithium chloride? % mass is grams of component/total mass of mixture $\times 100$.

Exercise 60.0 grams of dextrose are added to 200. grams of water. What is the % mass of dextrose? What is the % of water?

You can't always find the solution concentration you need. It's common to have to dilute a more concentrated solution to create what you want. The dilution formula is

$$M_1 V_1 = M_2 V_2$$

where M is molarity and V is volume.

1.3 Colligative Properties

Colligative properties of solutions are properties that depend on the amount of solute particles.

Colligative properties only occur when a nonvolatile solute is added. Nonvolatile means it doesn't evaporate easily, so the solutes are usually solid.

4 important properties

- Freezing point of solution is lowered
- Boiling point of solution is raised
- Vapor pressure of solution is lowered
- Osmotic pressure is raised

Freezing point can be lowered by adding a nonvolatile solute to water, and the "depression", or specific number by which the freezing point is lowered, can be calculated.

The formula for this is

$$\Delta T = K_f m i$$

Where, ΔT is the change in freezing point, K is the molal freezing point constant, m is molality, and i is the number of particles from one "formula" of the solute.

Boiling point is increased by adding a nonvolatile solution, and the "elevation", or specific number by which the BP is elevated, can be calculated.

$$\Delta T = K_b m i$$

where K_b is the molal boiling point constant, and the other variables are defined above.

Vapor pressure lowering - the greater the number of solute particles in a solution, the lower the vapor pressure of the liquid solvent. The resulting vapor pressure is equal to the vapor pressure of the pure solvent times the mol fraction of the solvent.

$$P = P_{\text{solvent}} \cdot X_{\text{solvent}}$$

Osmotic pressure is the pressure required to stop osmosis from happening. Osmosis is the transfer from a dilute solution to a more concentrated one - osmosis is trying to balance out concentrations. Osmotic pressure increases with increased solute in a solution.

$$P_{os} V = nRT$$

When we previously mentioned that not all ionic compounds dissolve, there is a catch to this. They do dissolve a little, but most of the ionic compound stays in solid form, a bit will dissolve into aqueous ions. An "equilibrium" is reached between the solid and aqueous phases.

In order to determine how much actually dissociates, we have to be able to write what is called an "equilibrium expression".

Note:

- square brackets indicate concentration
- Ion charges are included inside the brackets
- Coefficients become exponents
- Solids and liquids have a concentration of 1

Exercise Write the K_{sp} expression for Lead(II) fluoride.

We can use the K_{sp} expression to determine how much of the substance will actually dissolve.

Math problems with equilibrium will almost always involve "RICE" tables -

- Reaction

- Initial Concentration
- Change in concentration
- Equilibrium concentration

Exercise What is the solubility of a saturated lead(II) chloride solution? K_{sp} for lead(II) chloride is 1.17×10^{-5} .

Chapter Problems

1. Why are gases less soluble at high temperatures?
2. What is a suspension and how is it different from a colloid? Explain the difference in definition and physical properties.
3. How many grams of solute are contained in a solution of 142 mL of 1.40 M potassium sulfate.
4. Calculate the mole fraction of the salt in a solution of 15.7 g of sodium chloride in 100.0 g of water.
5. How many milliliters of 0.400 M HBr solution can be made from 50.0 mL of 8.00 M HBr solution?
6. You have a container of powdered copper(II) sulfate (CuSO_4) and all standard lab equipment. For a lab, you need 1.00 L of 2.00 M solution. Create a numbered list describing the steps necessary to create the solution. Show all necessary calculations needed.
7. Explain on a particle basis why the vapor pressure of a solution is lower than a pure solvent.
8. A rock salt (NaCl), ice, and water mixture is used to cool milk and cream to make homemade ice cream. How many grams of rock salt must be added to water to lower the freezing point by 10.0°C ?
9. Write the correct formula for Lead(II) nitrate and determine if it is a strong electrolyte or not.
10. Write the correct formula for sodium permanganate and determine if it is a strong electrolyte or not.
11. Calculate the K_{sp} of the salt MgF_2 , whose solubility is 2.7×10^{-3} mol/L.
12. Calculate the K_{sp} of $\text{AgC}_2\text{H}_3\text{O}_2$ given that the solubility is 1.02 g/100 mL.