Mixtures of Compounds

The nature of solutions and concentration in g/ml, percents and molar units.

9.1 Mixtures and Solutions

- **Heterogeneous mixture:** A nonuniform mixture that has regions of different composition.
- **Homogeneous mixture:** A uniform mixture that has the same composition throughout.
- **Solution** A homogeneous mixture that contains particles the size of a typical ion or small molecule.

Solutions

- What makes a solution?
- Concentrations of Solutions
- Molarity – Important when we need to know how many moles there are of something in a mixture.
- g/ml - Easy to use if you have a balance or if you know how much you need in grams. Often used in medicine.
- Concentrations by % - Usually used when the parts of the mixture are present in close to the same amounts.

Making Solutions

- A solution is made when 2 or more compounds mix, and form a homogeneous solution.
- In order for this to happen the solution has to be more stable than the two separate compounds.
- When, oil, and oil-like molecules, come in contact with water they generally won't mix with it. Oil-like molecules disrupt the structure of liquid water, this keeps oil-like molecules out of the water.

- In pure water the molecules interact due to polar interactions and hydrogen bonding. The polar interactions are called dipole-dipole interactions.
- Neither of these types of interacts can occur with non-polar molecules.
- Polar molecules have partially positive and negative regions due differing electronegativities of the atoms that make up the molecules.
- Non-polar molecules are made up of elements that have approximately the same electronegativities, such as molecules made up of Carbon and Hydrogen, or that have positive and negative regions that cancel each other out.

Dipole-Dipole Interaction

- Molecules with dipoles can align themselves, somewhat like magnets, with the partially positively charged regions lined up with the partially negatively charged regions.

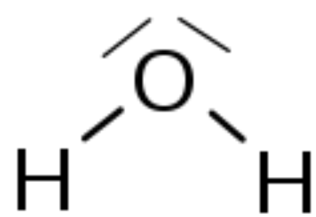
Dipole-Dipole Interaction

In liquids the molecules are moving past one another, and interactions are shifting, but the without these interactions the energy of the liquid would be less stable.

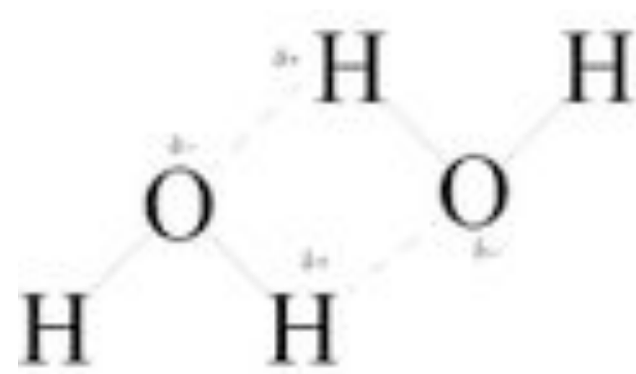
http://www.chem.unsw.edu.au/coursenotes/CHEM1/nonunipass/HainesIMF/dipoleinddipole.html

Hydrogen Bonding

- Hydrogen bonding occurs when 2 molecules almost share a hydrogen atom.

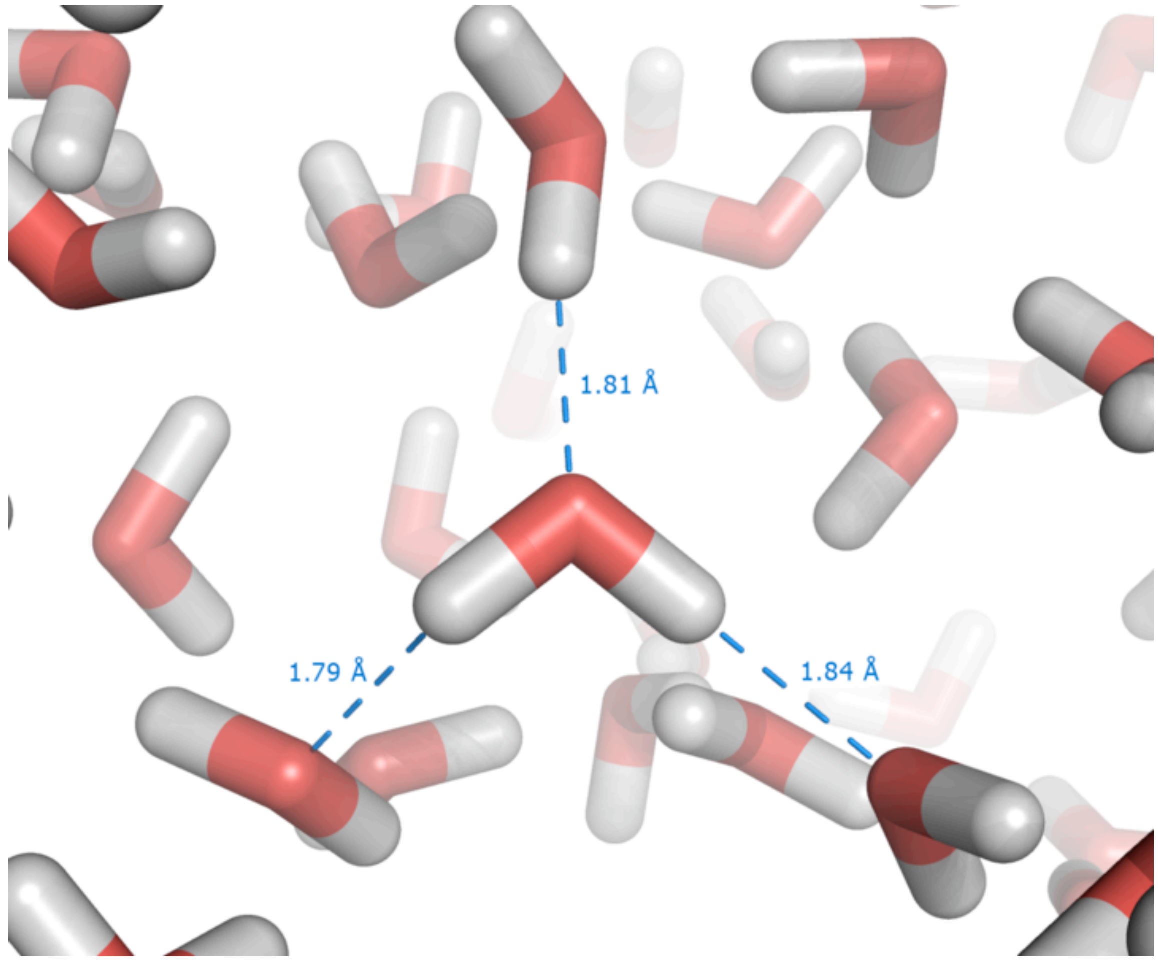


Water has a bent structure with 2 unpaired electrons that can interact with hydrogens on other water molecules



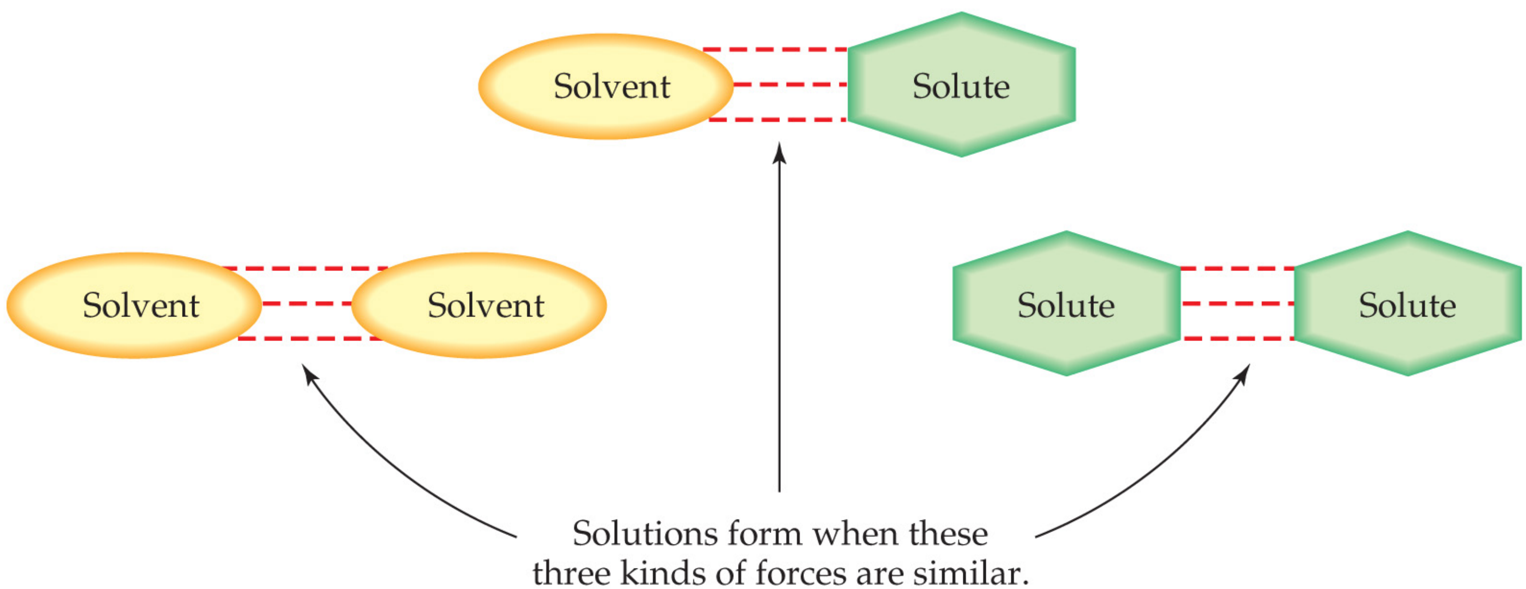
Hydrogen Bonding

Hydrogen bonds are important when water is liquid and when it is frozen as ice. In order for a solution to be made with water another the stabilizing effect of hydrogen bonding has to be balanced with something else.



Like Dissolves Like

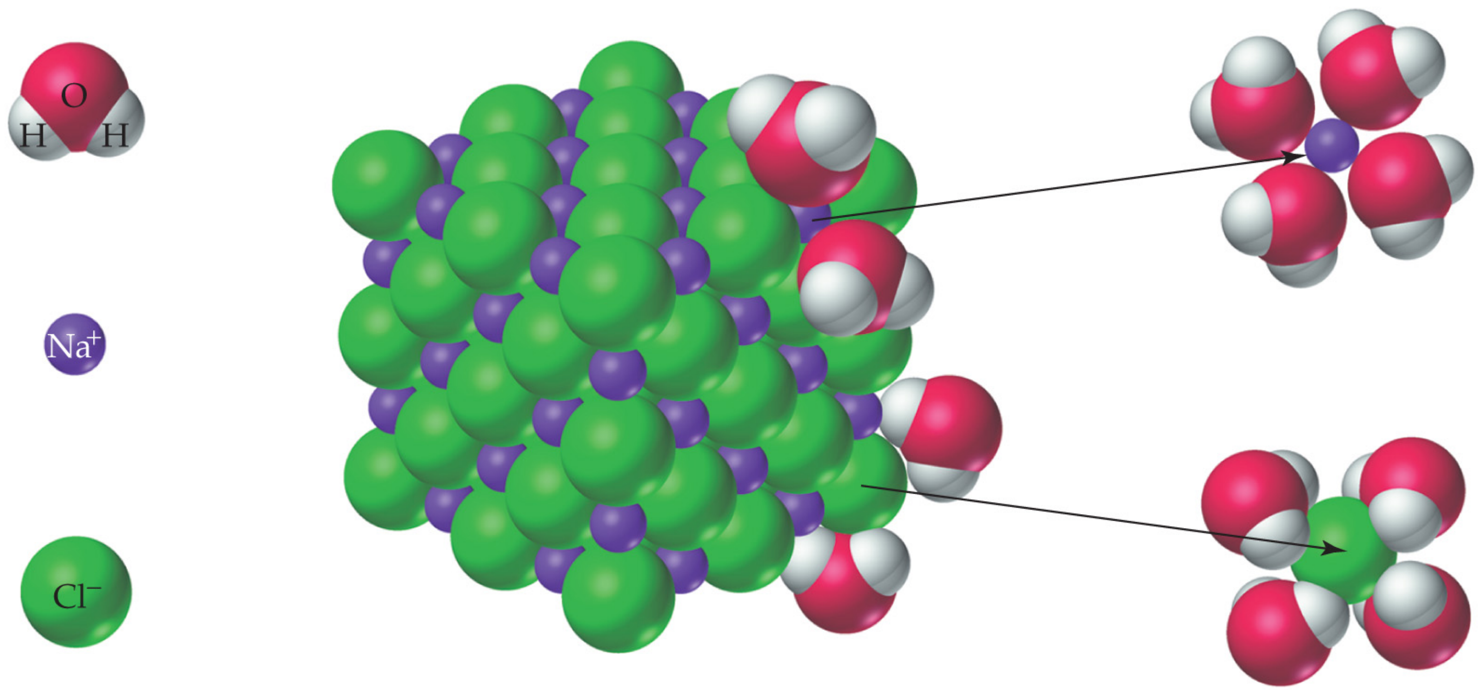
Substances with similar intermolecular forces form solutions and substances with different intermolecular forces do not. (The substances that are present in the smaller quantities are called the solutes. The one present in the greatest amount is called the solvent.)



Solubility and Miscibility

- Most substances reach the limit of a **saturated solution:** A solution that contains the maximum amount of dissolved solute that it can hold.
  - **Solubility:** The maximum amount of a substance that will dissolve in a given amount of solvent at a specified temperature.
  - Earlier this we observed this with slightly cloudy salt water, and when AgCl precipitated from the sea sample. Sodium chloride is pretty soluble in water but AgCl has a low solubility and so it could be collected by filtration.
- Occasionally two liquids are **miscible**, or soluble in all proportions. This occurs between water and ethyl alcohol, and between many compounds containing only carbon and hydrogen.

Dissolution of an NaCl crystal in water. Polar water molecules surround individual ions pulling them from the crystal surface into solution. Oxygen atoms point to (+) ions and hydrogen atoms point to (-) ions.



9.7 Units of Concentration

- **Solute:** A substance dissolved in a liquid.
- **Solvent:** The liquid in which a substance is dissolved.
- **Solution:** The combination of solute and solvent.
- A very useful means of expressing concentration in the laboratory is **molarity (M)**, the number of moles of solute dissolved per liter of solution.

$$\text{Molarity (M)} = \frac{\text{Moles of solute}}{\text{Liters of solution}}$$

Other Common Units of Concentration

- g/ml
- Volume/Volume Percent Concentration
- Mass/Mass Percent Concentration
- ppm (parts per million)
- ppb (parts per billion)

Molarity

- Most of the time in chemistry and biochemistry the concentration of a solution is given in molar unit.
- The symbol for molar units is “M”
- Frequently millimolar units are used and abreviated “mM”.

Calculating Molar Concentrations

- What is the concentration of a 2 liter solution that contains 1.895 moles of arsenic.

$$M = \left(\frac{moles\ of\ solute}{volume\ of\ the\ solution\ in\ liters} \right)$$

$$M = \left(\frac{1.895\ moles\ Arsenic}{2.0\ liters} \right)$$

$$M = 0.9475\ M = 0.95\ M$$

Arsenic is Nasty Stuff

- In the past it was used as a pesticide, and in pressure treated wood. (This is the type of wood that is commonly found on decking a play structures.)
- A 12x 6x2x4 board contains 27grams of arsenic. If this board were burnt, and the ashes mixed with 1.5 liters of water. What would the arsenic concentration in the mixture be?

Arsenic Problem

27 g Arsenic in 1.5 liters of water

- Find the # of moles of Arsenic

Molar Mass of Arsenic is 74.92160 g/mole

$$moles\ Arsenic = 27g \times \left(\frac{1\ mole}{74.92160\ g} \right) = 0.360\ moles\ As$$

- Calculate the Molarity

$$M\ \ As = \left(\frac{0.360\ moles\ As}{1.5L} \right) = 0.240M\ \ As = 0.24M\ \ As$$

Percent of the mass of the wood that is due to arsenic

- If the 12x6x4 piece of wood weighs 28 kg, what fraction of this weight is due to Arsenic?
- Convert Kg→g

$$mass\ of\ \ wood\ in\ grams = 28kg \times \left(\frac{1000g}{1kg}\right) = 28000g$$

- Use this mass to determine the mass%

$$\%As = \left(\frac{27g}{28000g}\right) \times 100\% = 0.0964\% = 0.096\%$$

ppb and ppm

- But this does not tell me enough what I need is to be able to relate this amount to toxicity data is in ppm and ppb not %. I need to find the % to make sense of these numbers.

Parts per Million (ppm) and **Parts per Billion (ppb):** When concentrations are very small, as often occurs in dealing with trace amount of pollutants or contaminants, parts per million (ppm) or parts per billion (ppb) units are used.

$$\text{ppm} = \frac{\text{Mass of solute (g)}}{\text{Mass of solution (g)}} \times 10^6 \quad \text{or} \quad \frac{\text{Volume of solute (mL)}}{\text{Volume of solution (mL)}} \times 10^6$$

$$\text{ppb} = \frac{\text{Mass of solute (g)}}{\text{Mass of solution (g)}} \times 10^9 \quad \text{or} \quad \frac{\text{Volume of solute (mL)}}{\text{Volume of solution (mL)}} \times 10^9$$

Calculating ppm and ppb

- ppm-parts per million

$$ppm\ As = \left(\frac{27g}{28000g}\right)\times 10^{6} = 964\,ppm = 960\,ppm$$

- That looks like a big number in ppm, in turns out though that the EPA limit in water is in ppb. So lets try to get the correct units this time.

$$ppb\ As = \left(\frac{27g}{28000g}\right)\times 10^{9} = 964000\,ppb = 960000\,ppb$$

Checking with the EPA

- According to the EPA the maximum allowable level of Arsenic in water is 50 ppb, with many suggesting that 2ppb is more appropriate limit. I am not sure how this would relate to Arsenic in wood.
- But we still need to get rid of the toxic ash water.
- How about if we just dilute it. How much water would we need to add to reach EPA standards.

9.8 Dilution

- **Dilution:** Lowering concentration by adding additional solvent.
- **Dilution factor:** The ratio of the initial and final solution volumes (V_1/V_2).
- In the dilution process, the amount of solute remains constant, only the volume is increased.
- Moles of solute = $M_cV_c = M_dV_d$ = constant
- Dilution equations can be generalized to other concentration units, $C_cV_c = C_dV_d$

- M_c and V_c refer to the Molar concentration of the more concentrated solution. V_d and M_d refer to the volume and molar concentration of the dilute solution made from the concentrated solution.

9.9 Ions in Solution: Electrolytes

- **Electrolyte:** A substance that produces ions and therefore conducts electricity when dissolved in water.
- **Strong electrolyte:** A substance that ionizes completely when dissolved in water.
- **Weak electrolyte:** A substance that is only partly ionized in water.
- **Nonelectrolyte:** A substance that does not produce ions when dissolved in water.

9.10 Electrolytes in Body Fluids: Equivalents and Milliequivalents

- What happens if NaCl and KBr are dissolved in the same solution? The cations and anions are all mixed together so an identical solution could just as well be made from KCl and NaBr. We can only speak of having a solution with four different ions in it.
- A similar situation exists for blood and other body fluids, which contain many different anions and cations. Since they are all mixed together, it is difficult to talk about specific ionic compounds.
- Instead, we are interested only in individual ions and in the total numbers of positive and negative charges. We need a new term, **equivalents** of ions.