Solutions

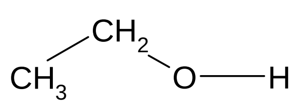
Definitions pertaining to solutions

Solute is the substance that is dissolved. It is usually present in the smaller amount.
Solvent is the substance that does the dissolving. It is usually present in the larger amount.
Solubility is the limit to which something dissolves. It is the maximum amount of solute for a given amount of solvent.
A **saturated** solution is one that is at the solubility limit.
An **unsaturated** solution is one that is less than saturated.

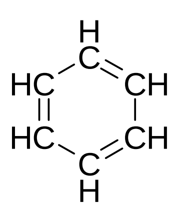
The solution process

Molecular solutes

A molecular substance will dissolve in a particular solvent depending on the types of intermolecular interactions present in the solute and the solvent. If the solute and solvent have similar interactions they will tend to dissolve in one another. If they do not they will not dissolve. Ethanol



has a structure similar to that of water. It also has similar intermolecular forces. Ethanol will dissolve in water in any proportion. However, benzene



only has London forces. It does not dissolve in water. The reason for this that is often given is that there are no attractions between the benzene molecules and the water molecules. This is not true. There are significant attractions between the two molecules. What makes benzene insoluble in water is that the attractions between individual water molecules are far stronger than the attractions between benzene molecules and water molecules. It is because of these stronger interactions that benzene molecules (or any other non-polar molecules) cannot penetrate between the water molecules.

Ionic solutes

All ionic solids dissolve in water to some extent. The ionic solids that are generally considered to be insoluble are only very slightly soluble (less than 0.01 g of solute per 100 mL of solution). What determines if an ionic solid is very soluble or only very slightly soluble? There are two competing interactions that determine this. The first is the strength of the ionic bond holding the ions together. The second is the strength of the ion-dipole interaction between the ions and the water. If the ionic bond is stronger the substance is only slightly soluble in water. If the ion-dipole interaction is stronger the substance is more soluble in water. Ions with higher charges will tend to have stronger ionic bonds. Smaller ions will tend to have larger ion-dipole interactions.

Solubility Rules

1. All ionic compounds of Group IA metals, Ammonium, acetate, and Nitrate are soluble.
2. All Halide compounds (Cl^-, Br^-, I^-) are soluble unless combined with Ag^+, Pb^{2+}, $Hg_2{}^{2+}$.
3. Most sulfate compounds are soluble except when combined with Ca^{2+}, Sr^{2+}, Ba^{2+}, Ag^+, Pb^{2+}, $Hg_2{}^{2+}$.
4. Most carbonates, phosphates, and sulfides are INSOLUBLE, except Rule 1.
5. Most hydroxides are insoluble except Group IA, Ca^{2+}, Sr^{2+}, Ba^{2+}.

Concentration Units

Percent units

There are three percent units that are commonly used, percent by mass, percent by volume and percent mass-volume. Percent by mass is defined as the ration of the mass of the solute to the mass of the solution multiplied by 100. Percent by volume is defined as the ratio of the volume of the solute to the volume of the solution multiplied by 100. Percent mass-volume is defined as the ratio of the grams of solute to milliliters of solution multiplied by 100.

$$\%(m/m) = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100$$

$$\%(v/v) = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100$$

$$\%(m/v) = \frac{\text{grams of solute}}{\text{mL of solution}} \times 100$$

Related to the percent units are the units parts per million, parts per billion and parts per trillion. These are calculated the same way as the percent units (part per hundred) except we multiply by a million, billion or trillion.

Molarity

Molarity (M) is defined as the ratio of the number of moles of solute to the total volume of the solution in liters.

$$M = \frac{\text{moles of solute}}{\text{Liters of } \mathbf{solution}}$$

Dilution

Oftentimes, in the lab, we wish to have a solution of a particular somewhat dilute concentration, but the only solutions commercially available are more concentrated that what we need. In this case, we need to dilute the concentrated solution to make the solution we need. The dilution process involves adding water. The number of moles of solute remains the same in a dilution, only the volume of the solution changes. We can calculate the number of moles in a solution if we know the volume and the molarity of the solution. This number must remain constant in a dilution. We can use the formula:

$$M_1V_1 = M_2V_2$$

In this formula, the M's are the molarities and the V's are the volumes. It does not matter which is 1 or 2.

Concentrations and Stoichiometry

Because the volume and molarity of a solution will give us the number of moles of solute, which is usually the component of a solution that reacts, we can use it to do stoichiometric calculations. For solid substances, we use the molar mass. For gases, we use PVT data and the ideal gas law. For solutions, we use the volume and molar concentration. Just as before, the methodology of solving the problems is no different. We still calculate moles of A, convert it to moles of B and convert that to the desired unit.