Solutions

Solution: a mixture composed of a solute and solvent. The solute is the substance in the lower amount and the solvent is the substance present in the higher amount.

The concentration of a solution can be expressed in several different ways

Molarity: the number of moles of solute per liter of solution.

Molality: the number of moles of solute per kilogram of solvent.

Mass Percent: the percent by mass of solute in the solution

$$Mass\ Percent = \frac{mass\ of\ solute}{mass\ of\ solution} \times 100\%$$

Mole Fraction: the ratios of moles of a given component of the solution to the total number of moles of solution.

$$X_A = \frac{n_A}{n_T}$$

ex. A solution is prepared by mixing 1.00 g of ethanol (C_2H_5OH) with 100 g of water to a total volume of 101 mL. Determine the molarity, molality, mass percent, and mole fraction of ethanol in the solution.

ex. A solution of sulphuric acid with a concentration of 3.75 M has a density of 1.230 g/mL. Calculate the mass percent, molality, and mole fraction of sulphuric acid for 1.00 L of solution.

Ion Colours

Most transition metals have ions that display colours, for example, copper (II), Cu^{2+}, is blue and nickel (II), Ni^{2+}, is green. A notable exception is zinc.

Some polyatomic ions also display colours, for example, permanganate, MnO_4^-, is purple, chromate, CrO_4^{2-}, is yellow, and dichromate, $Cr_2O_7^{2-}$, is orange

Solubility

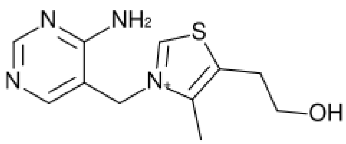
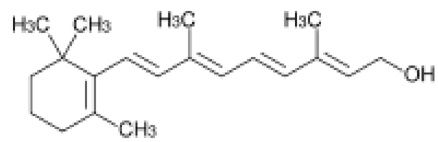
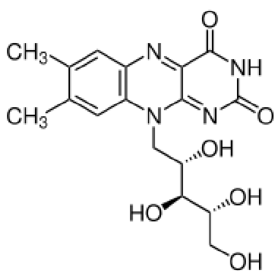
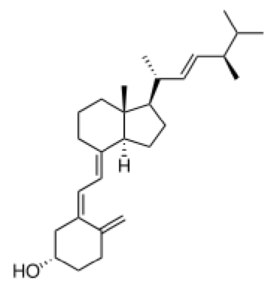
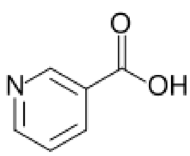
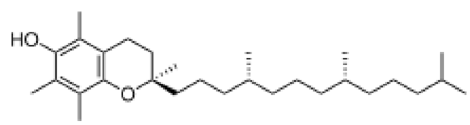
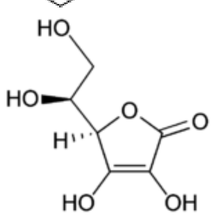
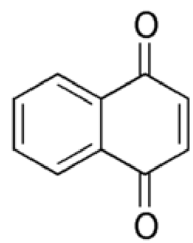
Solubility: the amount of a solute that will dissolve in a solvent in order to form a saturated solution.

Factors affecting solubility:

(1) Structure

- In general, “like dissolves like” (ie. polar solvents will dissolve polar solutes, and non polar solvents will dissolve non polar solutes)

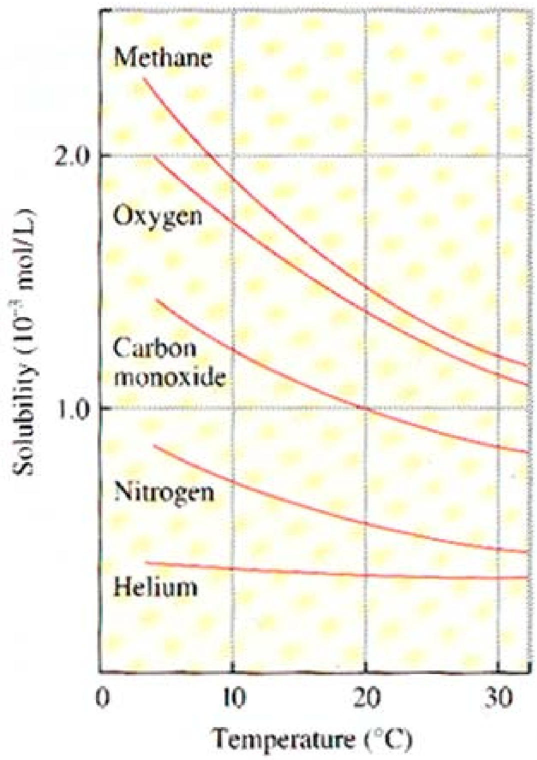
ex. Vitamins with a polar structure are water soluble, and vitamins with a predominantly non polar structure are fat soluble.

Water (polar) Soluble Vitamins		**Fat (non polar) Soluble Vitamins**	
	Vitamin B_1 (Thiamine)		Vitamin A
	Vitamin B_2 (Rioflavin)		Vitamin D
	Vitamin B_3 (Niacin)		Vitamin E
	Vitamin C		Vitamin K

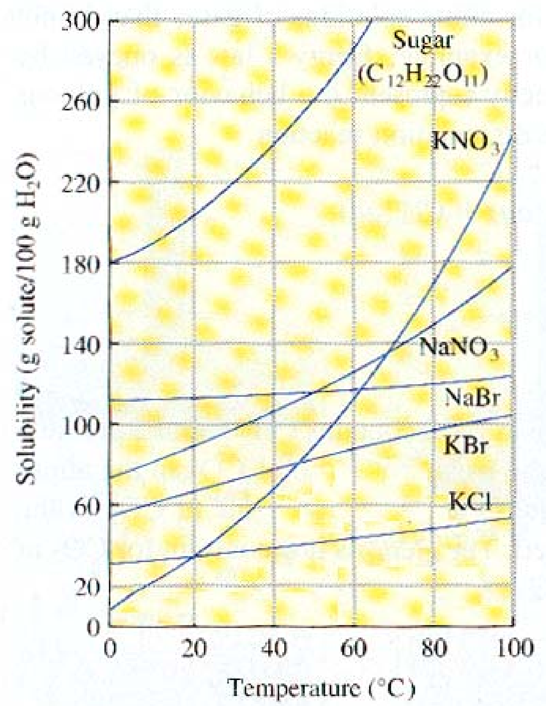
Polar molecules are often referred to as **hydrophilic** “water loving” and non polar molecules as **hydrophobic** “water fearing”.

(2) Temperature:
In general, the solubility of gases decreases at higher temperatures and the solubility of salts increases at higher temperatures. (note: there are exceptions to these trends.)

Solubility for Gases



Solubility For Solids

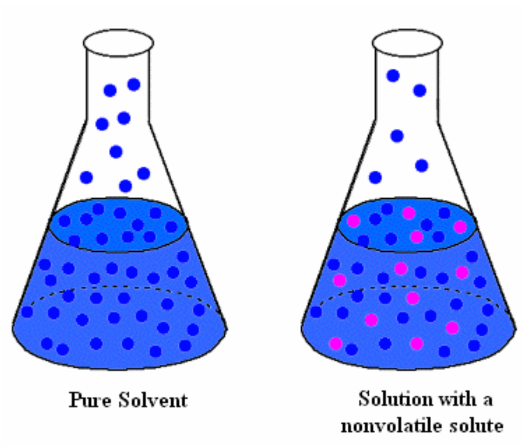


(3) Pressure
Pressure does not change significantly change the solubility of solids, but it does affect the solubility of gases. In general increased pressure increases the solubility of a gas.

ex. When a can of pop is opened, the pressure suddenly decreases. As a result, the solubility of the dissolved carbon dioxide decreases and there is fizzing as the gas molecules leave the solution.

Vapour Pressure of a Solution

Solutions of nonvolatile solutes will be considered, as the solute will remained dissolved in the solution.
In general, the presence of a solute results in a solution having a lower vapour pressure than that of the pure solvent.



The presence of a solute decreases the number of solvent molecules present at the surface of the solution, and therefore lowers the number of solvent molecules that can escape to the vapour phase, therefore decreasing the vapour pressure.

The vapour pressure of a solution can be calculated according to Raoult's Law:

$$P_{solution} = X_{solvent} P_{solvent}$$

Where: $P_{solution}$ = the vapour pressure of the solution
$X_{solvent}$ = the mole fraction of the solvent
$P_{solvent}$ = the vapour pressure of the pure solvent

ex. Calculate the vapour pressure of a solution made by dissolving 158.0 g of sucrose ($C_{12}H_{22}O_{11}$) in 643.5 mL of water. At 25 ºC, the density of water is 0.9971 g/mL and the vapour pressure is 23.76 torr.

ex. A solution is prepared by adding 20.0 g of urea to 125 g of water at 25 ºC. The observed vapour pressure of the solution was found to be 22.6 torr. Calculate the molar mass of urea.

For ionic compounds, it is important to consider that, in solution, the compound will dissociate into its component ions. As a result, the total number of moles of solute will be the total number of moles of ions.

ex. Calculate the vapour pressure of a solution made by mixing 35.0 g of sodium sulphate with 175 g of water at 25 ºC.

Liquid-Liquid Solutions
In liquid-liquid solutions, both the solute and solvent may be volatile. Solutions that closely follow Raoult's law are called ideal solutions whereas solutions that do not closely follow Raoult's Law are called non ideal solutions. Ideal behaviour is generally observed if the solute and solvent have similar properties to one another; however, if the solute and solvent experience a strong intermolecular force (ie. hydrogen), non ideal behaviour can result.

ex. Consider the following solutions:

Solution	**Ideal or Non Ideal?**
Ethanol and Water	
Ethanol and Benzene	
Benzene and Toluene	

Electrolytes and Non Electrolytes
Solutes can generally be classified into electrolytes and non electrolytes.
Electrolytes are solutes that dissociate to produce ions where are non electrolytes will not dissociate and will not produce ions.

Strong electrolyes: compounds that will completely dissociate in water. Includes soluble ionic compounds, strong acids, and strong bases.

Weak electrolytes: compounds that exhibit a small degree of dissociation in water. Includes weak acids (including carboxylic acids) and weak bases.

Non electrolytes: compounds that will not dissociate in water. Includes most organic compounds.

A solution of an electrolyte will conduct electricity and a solution of a non electrolyte will not conduct electricity. A strong electrolyte will form a solution that conducts electricity better than a weak electrolyte.

Colligative Properties

Colligative properties: properties of a solution that depend on the number of solute particles.

Boiling Point Elevation

A non volatile solute will increase the boiling point of the solvent. Recall, the boiling point of a liquid will occur when the vapour pressure of the liquid is equal to 1.00 atm. Due to the fact that a non volatile solute decreases the vapour pressure of a solution relative to that of the pure solvent, the solution must be heated to a higher temperature in order for the vapour pressure to reach 1.00 atm. The increase boiling point of a solution can be calculated according to the following equation:

$$\Delta T_b = iK_b m$$

Where: ΔT_b = The difference between the boiling point of the solution and that of the pure solvent (K)
i = van't Hoff factor, the number of particles in the solution for each solute molecule
(i will be equal 1 for non electrolytes and can be approximated as 1 for weak electrolytes)
K_b = The molal boiling point constant of the solvent (Water has K_b = 0.51 K kg/ mol)
m = the molality of the solute in the solution (mol/kg)

ex. Calculate the boiling point of a 1.0 molal solution of magnesium chloride in water.

Freezing Point Depression

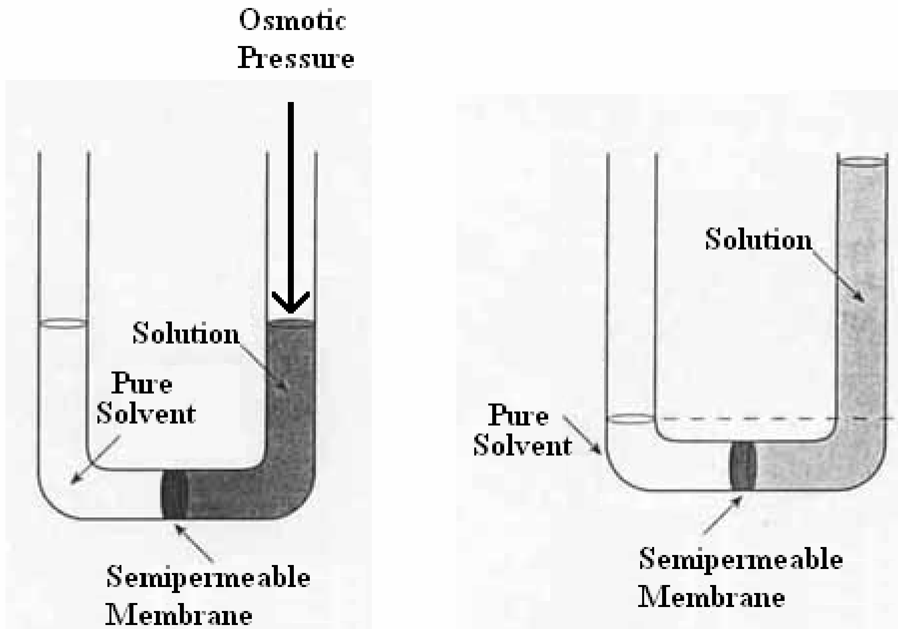
A non volatile solute will decrease the freezing point of the solvent. The decrease in freezing point of a solution can be calculated according to the following equation:

$$\Delta T_f = iK_f m$$

Where: ΔT_f = The difference between the freezing point of the solution and that of the pure solvent (K)
i = number of particles in the solution for each solute molecule
(i will be equal 1 for non electrolytes and can be approximated as 1 for weak electrolytes)
K_f = The molal freezing point constant of the solvent (Water has K_f = 1.86 K kg/ mol)
m = the molality of the solute in the solution (mol/kg)

ex. A solution is made by dissolving 7.76 kg of ethylene glycol (the alcohol that is the main component of antifreeze) in 10.0 kg of water. The solution is found to have a freezing point of -23.3 ºC. Determine the molar mass of ethylene glycol.

Osmotic Pressure
Osmosis is the flow of a pure solvent into a solution through a semipermeable membrane. Osmotic pressure is the pressure that must be applied in order to stop osmosis. The pressure applied to the solution forces solvent molecules to pass through the membrane towards the side containing pure solvent at the same rate as solvent molecules are traveling towards the side containing the solution.



Initial State   Equilibrium

$$\pi = iMRT$$

Where: π = the osmotic pressure (atm)
i = van't Hoff factor, the number of particles in the solution for each solute molecule
M = the molarity of the solution (mol/K)
R = the gas constant (0.0821 Latm/mol K)
T = Temperature (K)

ex. Calculate the osmotic pressure for a 0.50 M solution of glucose at 37 ºC.