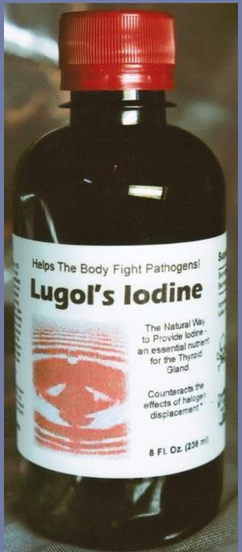
Solutions

Solutions are of great importance in the life and practical activities of man.

For example, solutions commonly used in medicine.



We shall consider:

-the definition of important concepts;

- classification of solutions;

- dissolution process;

- solubility;

- concentration of solutions;

- colligative properties of solutions;

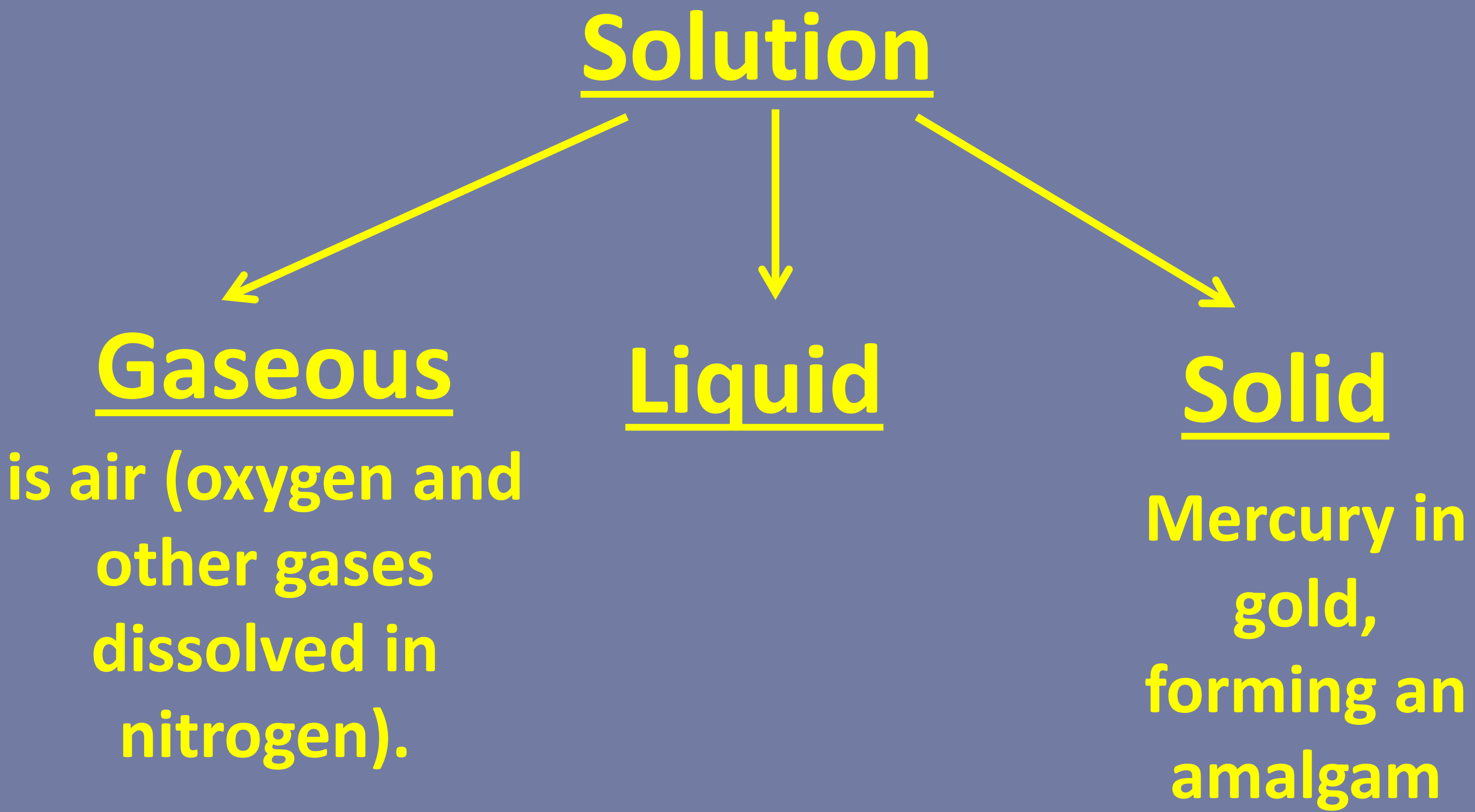
<u>Solute</u> **– the substance that dissolves to form a solution.**

<u>Solvent</u> **– the substance in which a solute dissolves.**

<u>Solution</u> **– a mixture of one or more solutes dissolved in a solvent.**

- The particles of solute in a solution cannot be seen by the naked eye.
- A solution is stable.
-The solute from a solution cannot be separated by filtration (or mechanically).
- It is composed of only one phase

Solvents can be gases, liquids or solids. The solution has the same physical state as the solvent.



Solution

Gaseous

is air (oxygen and other gases dissolved in nitrogen).

Liquid

Solid

Mercury in gold, forming an amalgam

Variables Affecting Solubility

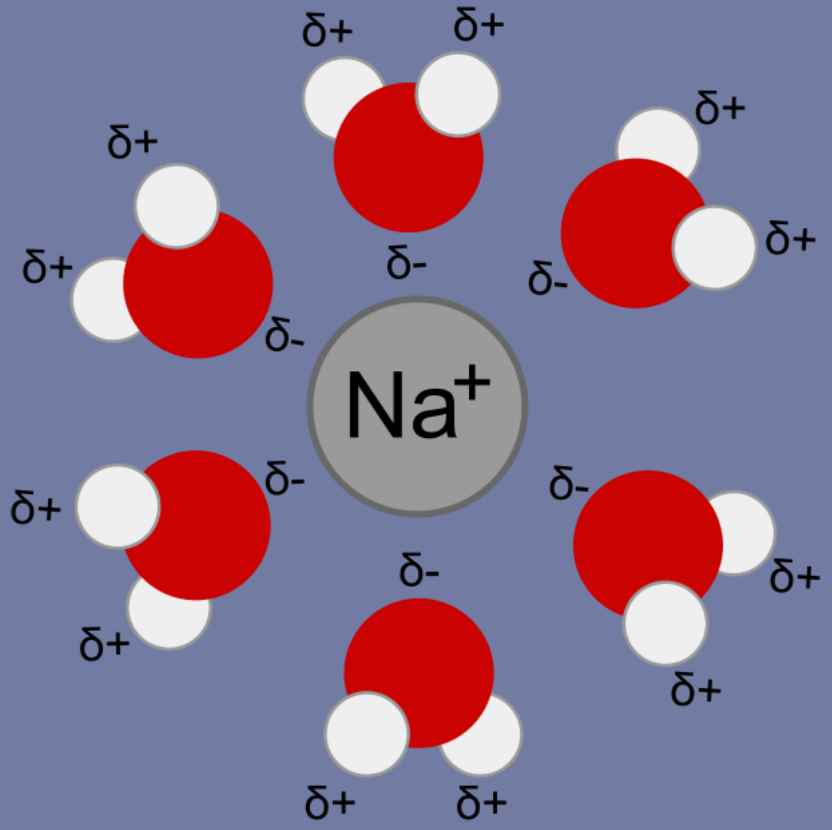
Factor	Concept	Example
Temperature	**Solids are more soluble in hot solvents, gases are more soluble in cold solvents**	**Sugar dissolves more readily in hot water, but CO_2 dissolves better in cold than warm water.**
Polarity	**Non-polar compounds dissolve in non-polar solvents, and polar compounds dissolve in polar solvents. "like dissolves like"**	**Alcohol and water are both polar, and they are miscible. Oil is non-polar and is immiscible in water.**
Pressure	**Gases dissolve better under higher pressure, due to greater forces pushing the gas molecules into the solvent.**	**Leaving the cap off a soda bottle will let the carbonation out.**

Dissolving

1 The forces between the particles in the solid must be broken. This is an endothermic process ($\Delta H>0$) called *dissociation*.

2 Some of the intermolecular forces between the particles in the liquid must also be broken. This is endothermic ($\Delta H>0$).

3 The particles of the solid and the particles in a liquid become attracted. This is an exothermic process ($\Delta H>0$) called *solvation*.


δ+
δ+
δ+
δ+
δ+
δ-
δ-
δ+
δ-
Na$^+$
δ-
δ-
δ+
δ-
δ+
δ+
δ+
δ+
δ+

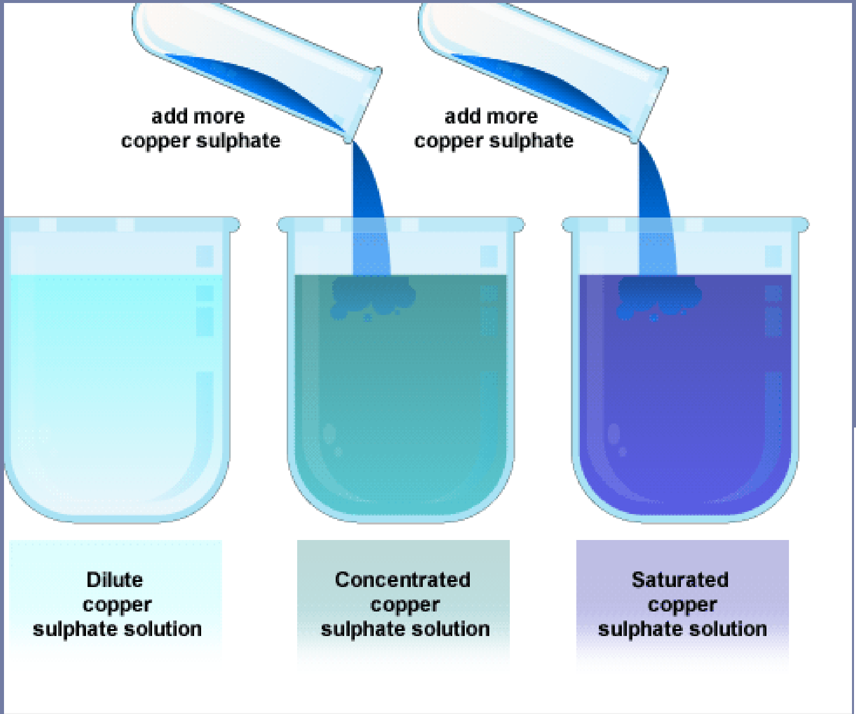
Saturation

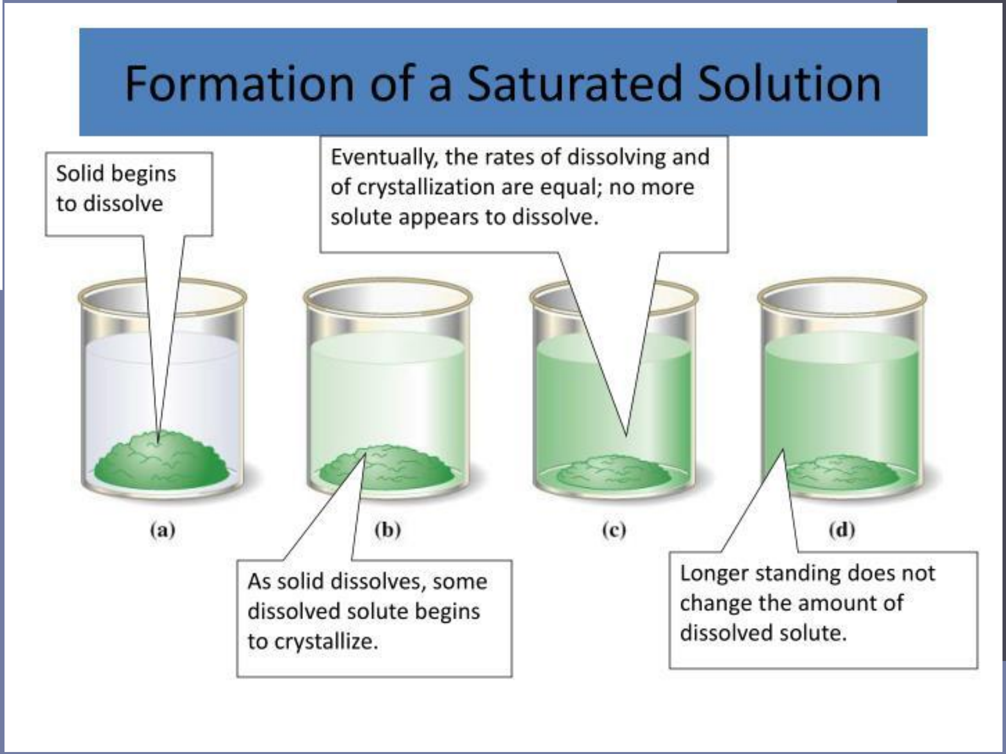
When a solution can hold no more solute, it is said to be saturated. This occurs when there is an *equilibrium* between the dissolved and undissolved solute.

If more solute can be added, the solution is unsaturated.

If a solution has more solute than is normally possible, due to the lowering or heightening of temperature, it is said to be supersaturated. If disturbed, the solution will rapidly form solid crystals.

Solubility is the measure of how many grams of solute can dissolve in 100 grams of solvent (or in the case of water, solute per 100 milliliters.)





Formation of a Saturated Solution

Solid begins to dissolve

Eventually, the rates of dissolving and of crystallization are equal; no more solute appears to dissolve.

As solid dissolves, some dissolved solute begins to crystallize.

Longer standing does not change the amount of dissolved solute.

Concentration of solutions can be Expressed in different ways

1 percent by mass

is the mass of solute divided by the total mass of the solution, (multiplied by 100 %).

$$\text{Percent by mass} = \frac{\text{mass of solute}}{\text{total mass of solution}}$$

2 Molarity

Molarity is the number of moles of solute per liter of solution. It is abbreviated with the symbol M, and is sometimes used as a unit of measurement.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

3 Normality

Normality is the number of moles of solute equivalents per liter of solution. It is abbreviated with the symbol N, and is sometimes used as a unit of measurement.

$$Normality = \frac{Equivalent\ of\ solute}{Liters\ of\ solution}$$

4 **Molality** is the number of moles of solute per kilogram of solvent. It is abbreviated with the symbol m, and is sometimes used as a unit of measurement.

$$Molality = \frac{number\ of\ moles\ of\ solute}{weight\ of\ solvent\ in\ kg}$$

5 **Mole fraction** the ratio of the number of moles of a given component of a mixture to the total number of moles of all the components.

$$X_1 = \frac{n_1}{n_1 + n_2} = \text{mole fraction of species 1}$$

$$X_2 = \frac{n_2}{n_1 + n_2} = \text{mole fraction of species 2}$$

$$X_1 + X_2 = 1$$

Colligative properties

Colligative means "depending on the collection" because the magnitude of the change is due to the number of particles in the solution and not their chemical identity. Examples of properties that fall under this category are:

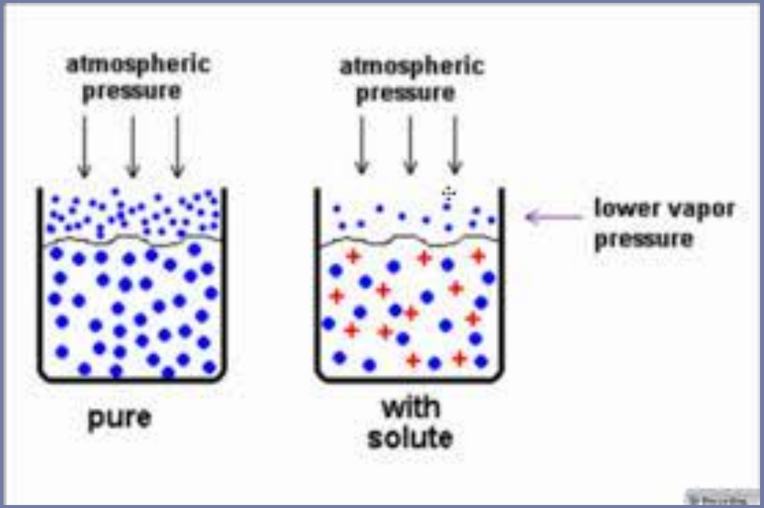
<u>the vapor pressure, melting and boiling points, and osmotic pressure.</u>

Vapor Pressure Lowering of Solutions

Solution has a lower vapor pressure than the pure solvent. Experiments on the vapor pressures of solutions containing nonvolatile solutes were carried out by Francois Marie Raoult (1830-1901). His results are described by the equation known as Raoult's law:

$$P_{solution} = X_{solvent} P^{o}_{solvent}$$

where $P_{solution}$ is the observed vapor pressure of the solution,
$X_{solvent}$ is the mole fraction of solvent,
and $P^{o}_{solvent}$ is the vapor pressure of the pure solvent.



Boiling-Point Elevation

The normal boiling point of a liquid occurs at the temperature where the vapor pressure is equal to 1 atmosphere. A nonvolatile solute elevates the boiling point of the solvent. The magnitude of the boiling-point elevation depends on the concentration of the particles of solute. The change in boiling point can be represented by the equation:

$$\Delta T_{b} = K_{b} m_{\text{solute}}$$

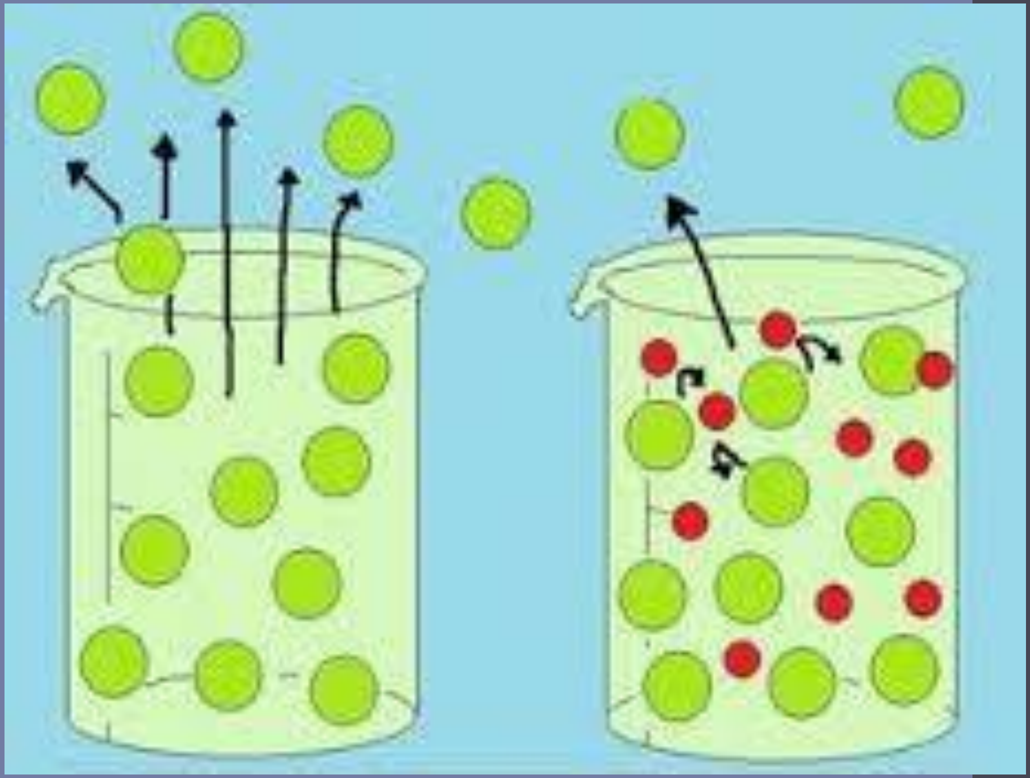
where

ΔT_b is the boiling-point elevation,

K_b is a constant that is characteristic of the solvent and is called the molal boiling-point elevation constant;

m_{solute} is the molality of the solute in the solution.

Adding a salt to water will increase the temperature at which it boils.



Freezing-Point Depression

When a solute is dissolved in a solvent, the freezing point of the solution is lower than that of the pure solvent. The equation for freezing-point depression is analogous to that for boiling-point elevation:

$$\Delta T_f = K_f m_{solute}$$

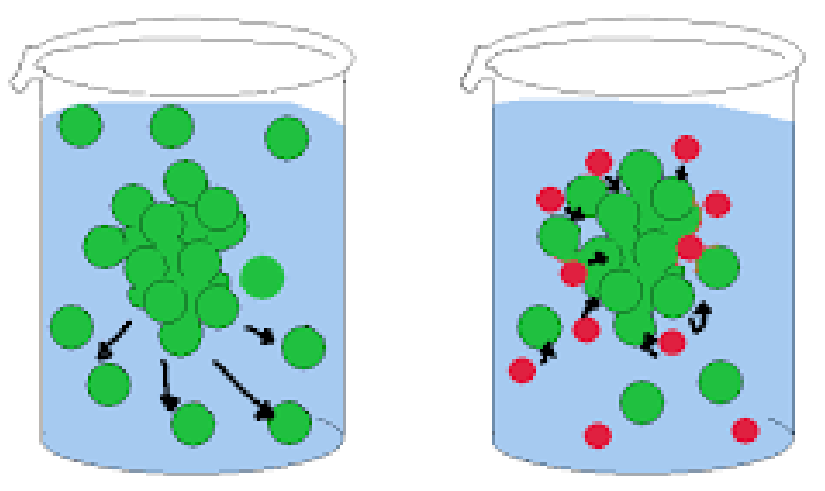
where

ΔT_b is the freezing-point depression,

K_f is a constant that is characteristic of the solvent and is called the molal freezing-point depression constant;

m_{solute} is the molality of the solute in the solution.

Adding a salt to water will lower the temperature at which it freezes.



Molal Boiling Point Elevation and Freezing Point Depression Constants

Compound	Normal boiling point	K_b (°C/m)	Normal freezing point	K_f (°C/m)
Water, H_2O	100.0	0.52	0.0	1.86
Benzene, C_6H_6	80.1	2.53	5.5	5.12
Ethanol, C_2H_5OH	78.4	1.22	-114.6	1.99
Carbon tetrachloride, CCl_4	76.8	5.02	-22.3	29.8
Chloroform, $CHCl_3$	61.2	3.63	-63.5	4.68

Osmotic Pressure

A solution and pure solvent are separated by a semipermeable membrane, which allows solvent but not solute molecules to pass through. As time passes, the volume of the solution increases and that of the solvent decreases. This flow of solvent into the solution through the semipermeable membrane is called osmosis.

Because liquid levels are different when the liquid levels stop changing, there is a greater hydrostatic pressure on the solution than on the pure solvent. This excess pressure is called the osmotic pressure.

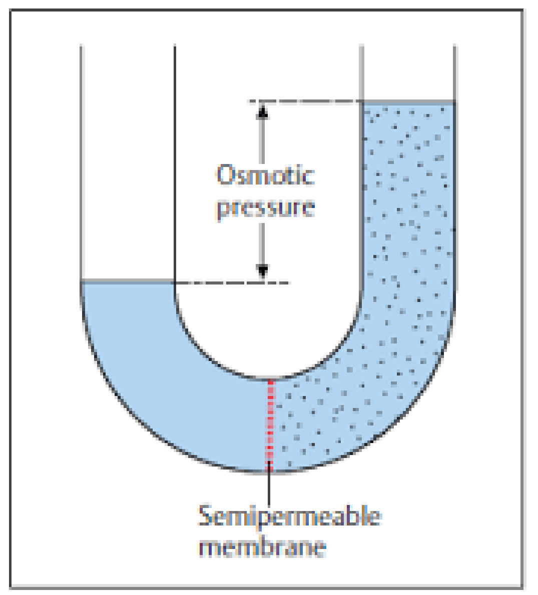
Experiments show that the dependence of the osmotic pressure on solution concentration is represented by the equation:

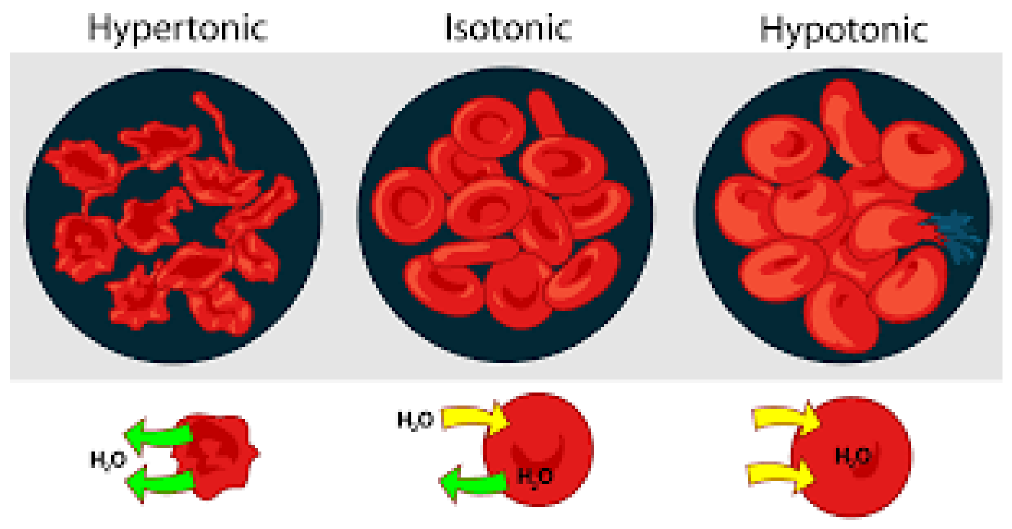
$$\Pi = MRT$$

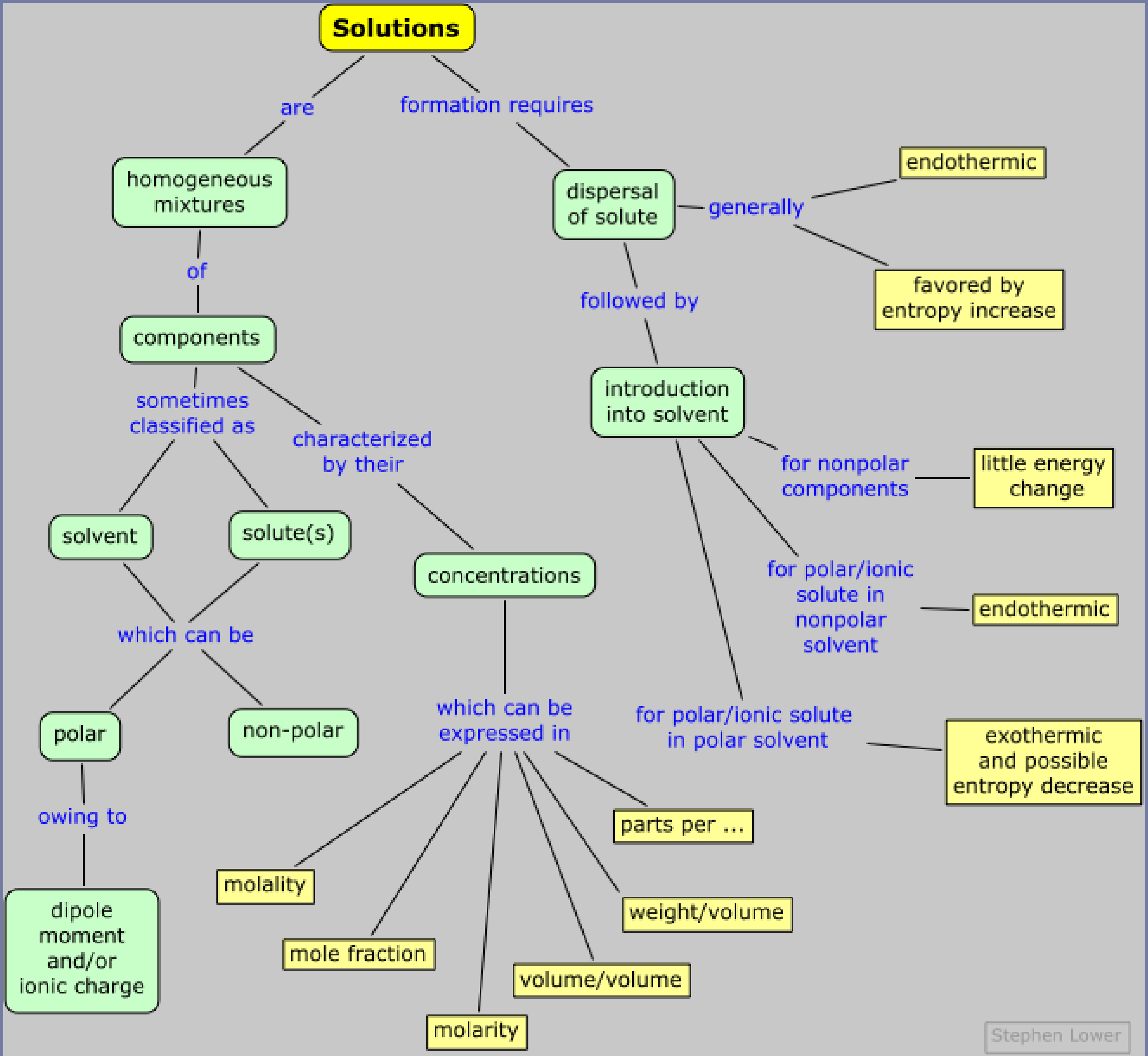
where
Π is the osmotic pressure in atmospheres,
M is the molarity of the solute, R is the gas law constant, and T is the Kelvin temperature.

Solutions that have identical osmotic pressures are said to be <u>isotonic solutions</u>.

If a solution in contact with pure solvent across a semipermeable membranes subjected to an external pressure larger than its osmotic pressure, reverse osmosis occurs. The pressure will cause a net flow of solvent from the solution to solvent.







Solutions

are

homogeneous mixtures

of

components

sometimes classified as

solvent

solute(s)

which can be

polar

non-polar

owing to

dipole moment and/or ionic charge

characterized by their

concentrations

which can be expressed in

molality

mole fraction

molarity

volume/volume

weight/volume

parts per ...

formation requires

dispersal of solute

generally

endothermic

favored by entropy increase

followed by

introduction into solvent

for nonpolar components

little energy change

for polar/ionic solute in nonpolar solvent

endothermic

for polar/ionic solute in polar solvent

exothermic and possible entropy decrease

Stephen Lower