Chapter 5

Solutions of non-electrolytes

Solutions of non-electrolytes

- Material may be mixed together to form solutions.
- The solutions may be
- True solution
- Colloidal solution
- Coarse dispersion

True solution

- A mixture of two or more components to form homogenous system (one phase) such as:
- Ethanol- water
- Sucrose – water
- Where the molecules of small amount (solute) disappear between the molecules of big amount component (solvent)

Colloidal solution

- A mixture of components which form heterogeneous system (two-phases) or homogenous system (one phase)
- The diameter of colloidal particles is between true and coarse dispersion, roughly (10–5000)**Å**
- Examples:
- Silver protienate in water heterogeneous colloidal
- Sodium carboxymethyl cellulose in water homogeneous colloidal
- The solution of two components is binary solution. The greater amount of component is call solvent and the lesser amount is solute

Coarse dispersion

- A mixture of components which form heterogeneous system (two-phases), emulsions (L+L) or suspension (S+L)
- . The diameter of particles is larger than 0.1Mm (1000Å) in

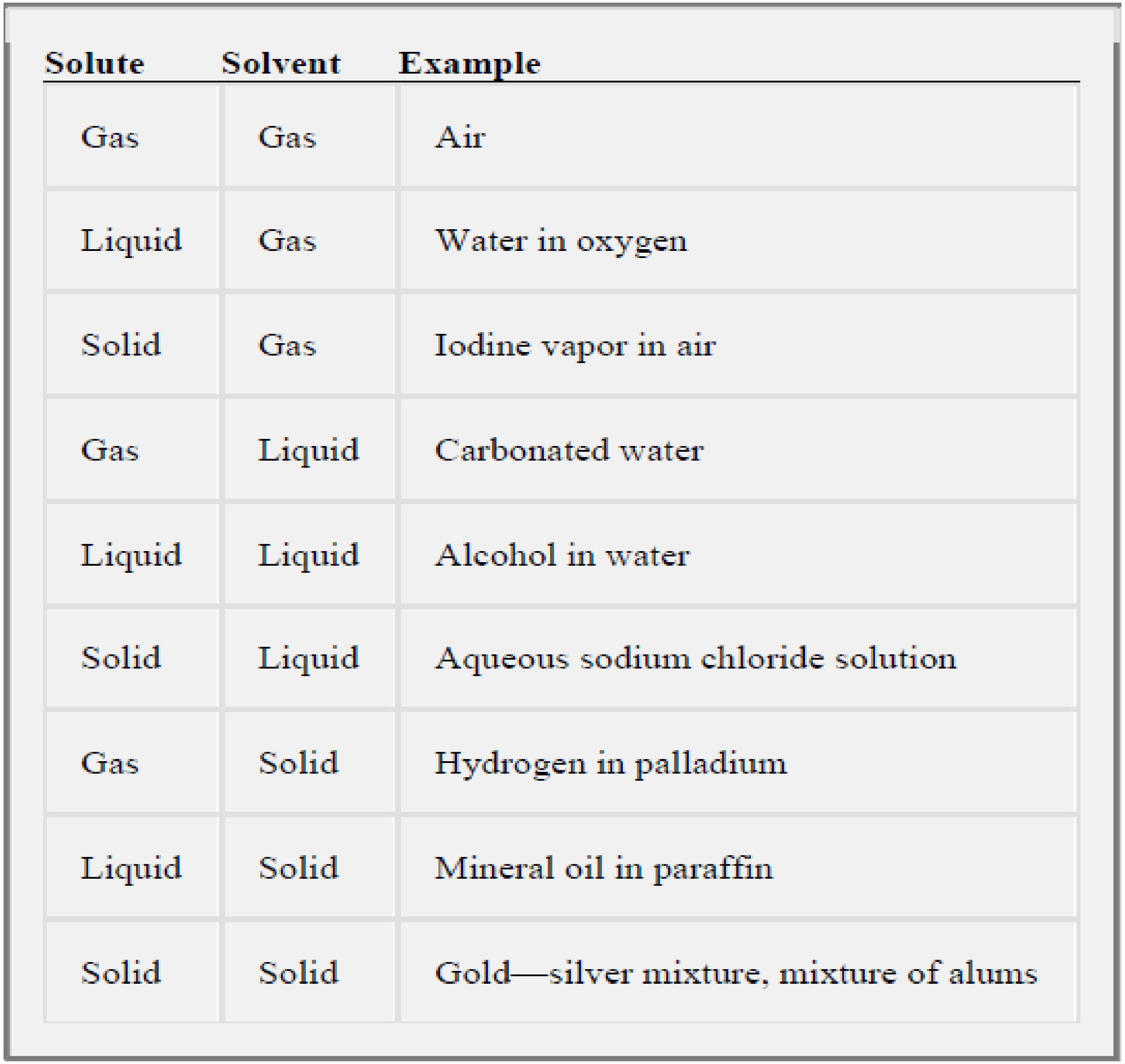
Properties of solution

- In general the physical properties of substance may be classified as:
- 1- Additive properties: which are depending the total contribution of atoms in molecules such as Mw
- 2- Constitutive properties: which are depending on the arrangement, number and kind of atoms in the molecules.
- Many physical properties are (partly constitutive and partly additive properties) such as refraction of light, electrical properties, surface characteristic, solubility are constitutive properties.

- 3- Colligative properties:
- which depend on the number of particles in the solution. It is same for equal concentrations of different non electrolyte solution, such as:
- Osmotic pressure (π), vapor pressure (v.p.) depression of freezing point (ΔT_f), elevation of boiling point (ΔT_b) are same for same concentration of non electrolyte solution

Types of solutions:

solutions maybe classified according to the state of solute and solvent, they are 9 types



Solute	Solvent	Example
Gas	Gas	Air
Liquid	Gas	Water in oxygen
Solid	Gas	Iodine vapor in air
Gas	Liquid	Carbonated water
Liquid	Liquid	Alcohol in water
Solid	Liquid	Aqueous sodium chloride solution
Gas	Solid	Hydrogen in palladium
Liquid	Solid	Mineral oil in paraffin
Solid	Solid	Gold—silver mixture, mixture of alums

Classification of solutions

- Solution can be classified in two main solution
- 1- Non electrolyte: which is don’t yielding ions when dissolved in water therefore don’t conduct an electric current through solution. Such as: (sucrose, glycerin, Naphthalene and urea)
- Non electrolyte produce the same colligative effects at the same concentration of solution.

2- electrolytes:

- Electrolyte substance which are forming ions in solution, conduct the electric current, produce greater colligative properties (such as ΔT_b and ΔT_f) than non electrolyte of the same concentration.
- (HCl aq, NaCl aq, Ephedrine aq, phenobarbital aq)

Subdivided of electrolyte solutions

- 1- strong electrolyte which completely ionized at (0.1 M) concentration
- HCl, NaCl, NaOH, ……
- 2- Weak electrolyte which is partially ionized at (0.1 M) concentration.
- HOAC, NH4OH, Ephedrine aq, phenobarbital aq

Concentration expression

- 1- Molarity: (M) number of moles of solute in one liter of solution
- **M= n/$V_{(L)}$ =W(g)/M_w (g.mol^{-1}) x 1000 $cm^3.L^{-1}$/V cm^3 mole.L^{-1}**
- 2- Normality: (N) number of equivalents of solute in one liter of solution.
- **N= n.of eq./$V_{(L)}$= W(g)/eq_w (g.eq^{-1}) x 1000 $cm^3.L^{-1}$/V cm^3 eq.L^{-1}**

	Mw	Eq w
H_2SO_4	98	49
Na_2CO_3	106	53
HCl	36.5	36.5

- 3- Molality: m number of moles of solute in one Kg of solvent.
- m= n.moles/ $W_{solvent}$

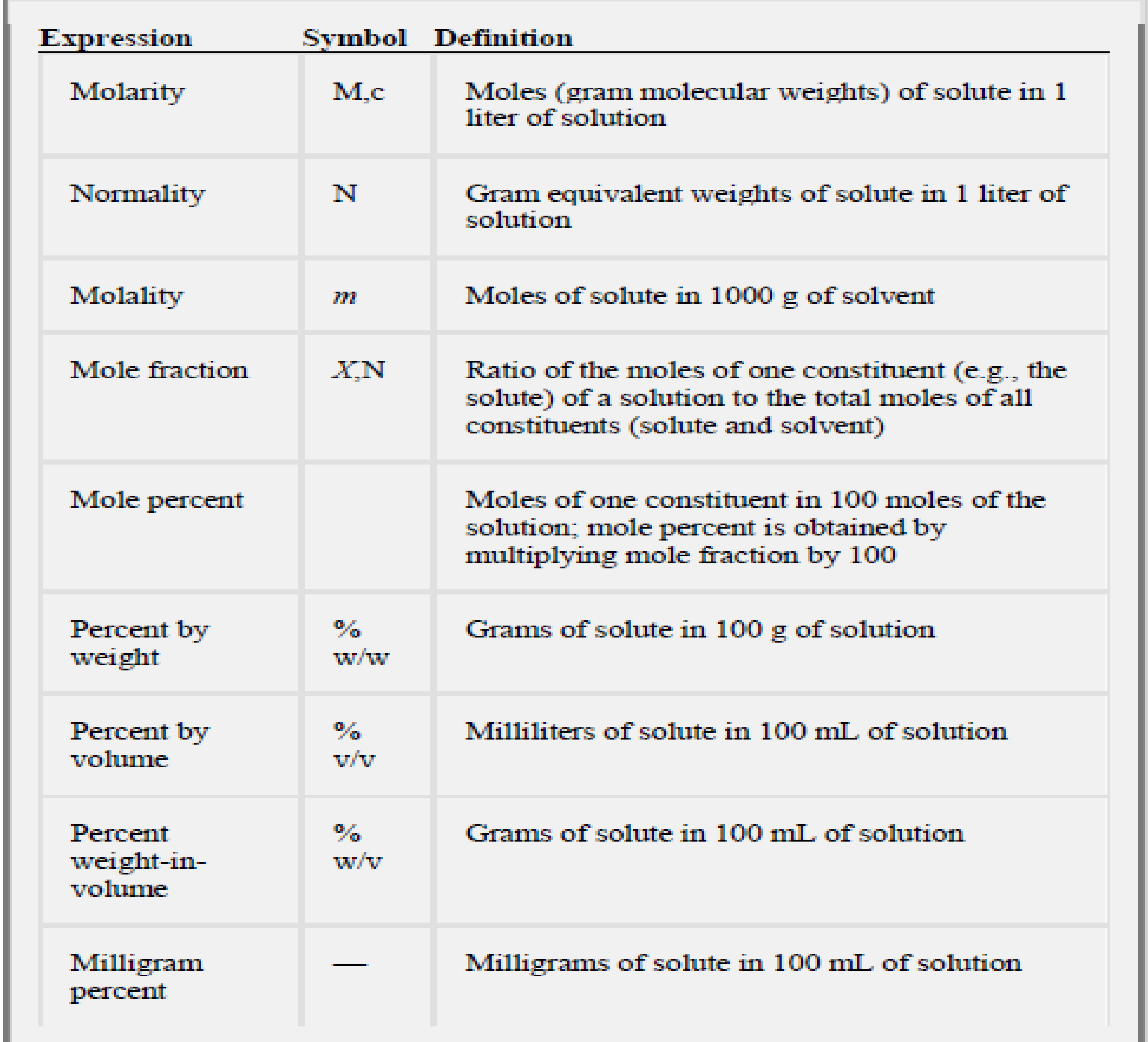
$=W_{solute}g/Mw(g.mol^{-1})X1000\ g.kg-1/W_{solvent}g$

4- mole fraction X

- The ratio of moles of one constituent (solute) of solution to the total moles of all constituents (solute + solvent).
- $X_1 = n_1/(n_1+n_2)$, $X_2 = n_2/(n_1+n_2)$
- Always: $X_1+X_2+\dots\dots X_i = 1$ *the total mole fraction is unity*
- **5- mole percent**: number of moles of constituent in 100 mole of solution
- $\%$ mole/mole= $X * 100\%$

- **6-Percent by weight**: number of grams of solute in 100 gram of solution
- %w/w= W_{solute} g/w_{solute} g+$w_{solvent}$g) x 100%
- **7-Percent by volume:** number of mL of solute in 100 mL of solution.
- % V/V= V_1 mL/(V_1mL+V_2mL) , 1=solute
  2= solvent
- **8- percent**: number of g of solute in100mL of solution
- %W/V= W_1/V mL of solution * 100%

- 9- milligram percent: number of mg of solute in 100 mL solution.
- $\%mg = W_{\mathbf{1\ mg}} / V_{\mathbf{mL\ solution}} \times 100\%$
- 10- part per million (ppm)
- $Ppm = W_{1\ mg} / V_{L\ solution} = W1_{Mg} / V_{mL\ solution}$
- 1 percent = 10^4 ppm= 10^7 ppb

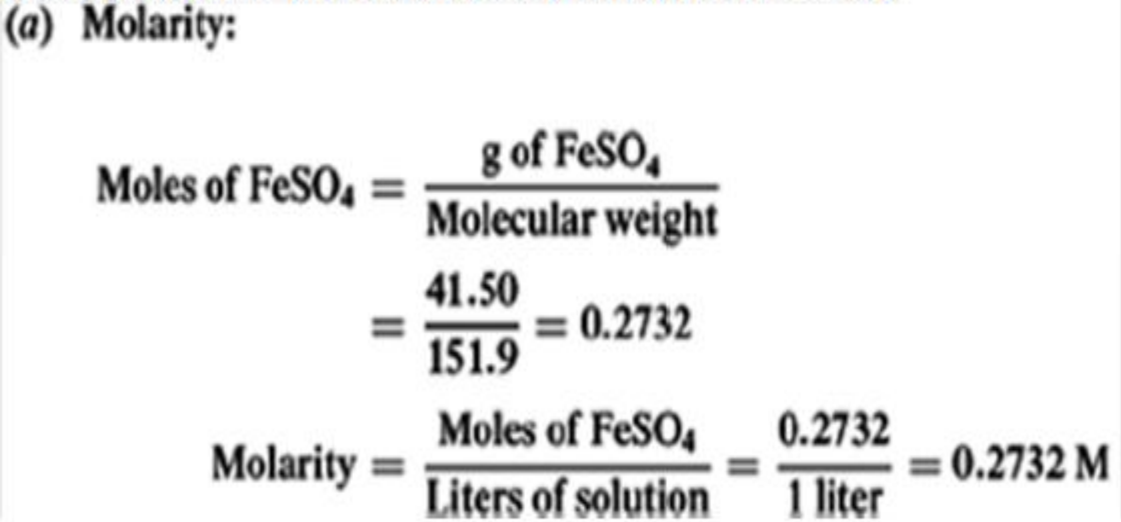


Expression	Symbol	Definition
Molarity	M,c	Moles (gram molecular weights) of solute in 1 liter of solution
Normality	N	Gram equivalent weights of solute in 1 liter of solution
Molality	m	Moles of solute in 1000 g of solvent
Mole fraction	X,N	Ratio of the moles of one constituent (e.g., the solute) of a solution to the total moles of all constituents (solute and solvent)
Mole percent		Moles of one constituent in 100 moles of the solution; mole percent is obtained by multiplying mole fraction by 100
Percent by weight	% w/w	Grams of solute in 100 g of solution
Percent by volume	% v/v	Milliliters of solute in 100 mL of solution
Percent weight-in-volume	% w/v	Grams of solute in 100 mL of solution
Milligram percent	—	Milligrams of solute in 100 mL of solution

Example 5-1

Solutions of Ferrous Sulfate

An aqueous solution of exsiccated ferrous sulfate was prepared by adding 41.50 g of $FeSO_4$ to enough water to make 1000 mL of solution at 18°C. The density of the solution is 1.0375 and the molecular weight of $FeSO_4$ is 151.9. Calculate (*a*) the molarity; (*b*) the molality; (*c*) the mole fraction of $FeSO_4$, the mole fraction of water, and the mole percent of the two constituents; and (*d*) the percentage by weight of $FeSO_4$.



(*a*) Molarity:

$$\text{Moles of FeSO}_4 = \frac{\text{g of FeSO}_4}{\text{Molecular weight}}$$

$$= \frac{41.50}{151.9} = 0.2732$$

$$\text{Molarity} = \frac{\text{Moles of FeSO}_4}{\text{Liters of solution}} = \frac{0.2732}{1\ \text{liter}} = 0.2732\ \text{M}$$

(*b*) **Molality:**

$$\text{Grams of solution} = \text{Volume} \times \text{Density}$$

$$1000 \times 1.0375 = 1037.5 \text{ g}$$

$$\text{Grams of solvent} = \text{Grams of solution} - \text{Grams}$$

$$\text{of FeSO}_4 = 1037.5 - 41.5 = 996.0 \text{ g}$$

$$\text{Molality} = \frac{\text{Moles of FeSO}_4}{\text{kg of solvent}} = \frac{0.2732}{0.996} = 0.2743\, m$$

(*c*) **Mole fraction and mole percent:**

$$\text{Moles of water} = \frac{996}{18.02} = 55.27 \text{ moles}$$

Mole fraction of $FeSO_4$:

$$X_2 = \frac{\text{Moles of FeSO}_4}{\text{Moles of water} + \text{Moles of FeSO}_4}$$

$$= \frac{0.2732}{55.27 + 0.2732} = 0.0049$$

Mole fraction of water:

$$X_1 = \frac{55.27}{55.27 + 0.2732} = 0.9951$$

Notice that
$X_1 + X_2 = 0.9951 + 0.0049 = 1.0000$
Mole percent of $FeSO_4 = 0.0049 \times 100 = 0.49\%$
Mole percent of water $= 0.9951 \times 100 = 99.51\%$

(*d*) **Percentage by weight of $FeSO_4$:**

$$= \frac{\text{g of FeSO}_4}{\text{g of solution}} \times 100$$

Ideal and real

solution

- An ideal gas defined as no interaction
- Ideal solution defined as no change in properties of components at mixing to form a solution. No heat evolved or absorbed and no change in volume, (no shrinkage or expansion)
- Ideality in gas is complete absence of interaction
- Ideality in solution is the complete uniform of attractive force. So that:
- $Pt=p^0{}_1X_1+p^0{}_2X_2$
- $Vt=V^0{}_1X_1+V^0{}_2X_2$
- $\Delta Ht= \Delta H^0{}_1X_1 +\Delta H^0{}_2X_2$
- $\eta t =\eta^0{}_1X_1+\eta^0{}_2X_2$

When we mixed

- 100mL MeOH +100mL EtOH=200mL solution
- No change in heat
- but
- 100mL H_2SO_4 +100 mL H_2O=180 mL solution
- With evolution of heat
- That mean in ideal solution
- **Cohesive attraction=Adhesive attraction**
- *Cohesive :between same type of molecules*
- *Adhesive: between deferent type of molecules*

of A and B from the surface of the liquid.

Example 5-6

Partial Vapor Pressure

What is the partial vapor pressure of benzene and of ethylene chloride in a solution at a mole fraction of benzene of 0.6? The vapor pressure of pure benzene at 50°C is 268 mm, and the corresponding p_A° for ethylene chloride is 236 mm. We have

$$p_B = 268 \times 0.6 = 160.8\ \text{mm}$$

$$p_A = 236 \times 0.4 = 94.4\ \text{mm}$$

If additional volatile components are present in the solution, each will produce a partial pressure above the solution, which can be calculated from Raoult's law. The total pressure is the sum of the partial pressures of all the constituents. In Example 5-6, the total vapor pressure P is calculated as follows:

$$P = p_A + p_B = 160.8 + 94.4 = 255.2\ \text{mm}$$

The vapor pressure–composition curve for the binary system benzene and ethylene chloride at 50°C is shown in Figure 5-1. The three lines represent the partial pressure of ethylene chloride, the partial pressure of benzene, and the total

pressure of the solution as a function of the mole fraction of the constituents.