By the end of today's class you will be able to:
1) Calculate molarity, molality and mole fraction.
2) Discuss differences between ideal and nonideal solutions.
3) Apply to Henry's Law to determine the solubility of a gas in a particular solvent.

SOLUTIONS & HENRY'S LAW

Solutions

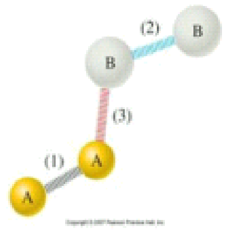
- **Solvent:** present in the largest amount.
- **Solute:** present in smaller amount.
- Solutions are **homogenous** – they have uniform properties.

Solution Formation

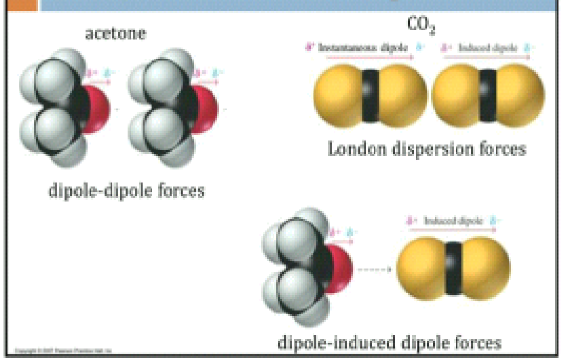
- Solvent molecules are separated from each other.
- Solute molecules are separated from each other.
- Solvent and solute molecules become attracted to each other.

Ideal Solution

Forces are similar between all components of the solution.



Nonideal Solution Example: Acetone and CO_2



Ideal vs. Nonideal Solutions

Ideal solutions:

- Volumes are strictly additive.
- Mixing is always complete.

Non-ideal solution:

- Volume is not the simple sum of the volumes of the component pure liquids.
- Solubility is not guaranteed over the whole composition range.

Examples of Solutions

TABLE 14.1 Some Common Solutions

Solution		Components
Gaseous solutions		
Air		N_2, O_2, and several others
Natural gas		CH_4, C_2H_6, and several others
Liquid solutions		
Seawater		H_2O, NaCl, and many others
Vinegar	mL of	H_2O, $HC_2H_3O_2$ (acetic acid)
Soda pop		H_2O, CO_2, $C_{12}H_{22}O_{11}$ (sucrose), and several others
Solid solutions (alloys)		
Yellow brass		Cu, Zn
Palladium–hydrogen		Pd, H_2

Composition of Solutions

- percentages
  - by mass
    - Ex: 25% (w/w) = 25 g solute per 100 g solution
  - by volume
    - Ex: 25% (v/v) = 25 ml solute per 100 ml solution
  - weight to volume
    - Ex: 25% (w/v) = 25 g solute per 100 ml solution
- mole fraction $$x_i = \frac{\overbrace{n_i}^{\text{\# of moles of solute}}}{\underbrace{n_1 + n_2 + \ldots + n_n}_{\text{total \# of moles}}} = \frac{n_i}{\sum_{j=1}^{n} n_j} \qquad \sum_{j=1}^{n} x_j = 1$$
- molarity = $\dfrac{\text{amount of solute (moles)}}{\text{volume of solution (liters)}}$ Temperature dependent!
- molality = $\dfrac{\text{amount of solute (moles)}}{\text{mass of solvent (kg)}}$

Example 1

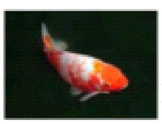
What are the molality and molarity of a solution of ethanol (C_2H_5OH) in water if the molar fraction of ethanol is 0.05? Assume that the density of the solution is 0.997 g/ml.

Example 2

A chemist titrates 25 ml of an H_3PO_4 solution with 0.205 M NaOH solution, and 35.75 ml are required to reach the endpoint. If only two hydrogen atoms in the H_3PO_4 react with the added OH^- ions in this titration, what is the molarity of the H_3PO_4 solution?

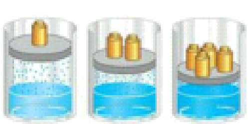
Solubility of Gas in Liquid Effect of Temperature

- Most gases (including N_2 and O_2) are less soluble in water as temperature increases.
- In organic solvents the reverse is often true.



Why do fish survive better in cold water?

Solubility of Gas in Liquid Effect of Pressure



Henry's Law

Solubility of a gas increase with increasing pressure.

- Generally applied to *gas-liquid solutions.*
- Relates the partial pressure of a gas to its molar fraction in the liquid at a given temperature.

$$P_i = k_i x_i$$

- k_i depends on ______________________

Henry's Law

Another commonly used form of Henry's Law is:

$$C_i = k_i P_i$$

- C_i represents the solubility of the gas in units of ml of gas per liter of solution.
- Units of k_i are ml of gas/(l solution · atm)

Example 3

Natural gas consists of about 90% methane, CH_4. Assume that the solubility of natural gas at 20 °C and 1 atm gas pressure is about the same as that of CH_4, 0.02 g/kg water. If a sample of natural gas under a pressure of 20 atm is kept in contact with 1.00×10^3 kg of water, what mass of natural gas will dissolve.

Example 4

In qualitative chemical analysis, it is common to saturate water solutions with H_2S (g). If H_2S (g) is bubbled through water at 25 °C with a total pressure of 1.0 atm, what would be the partial pressure of H_2S (g) in each bubble?

Use this value and the *k* value for H_2S to determine the molarity of H_2S in this solution. Assume a density of water of 1.00 g/ml.

Data: $k = 4.12 \times 10^5$ mmHg for H_2S
$P_{vap} = 3.126 \times 10^{-2}$ atm for H_2O

Suggested Readings

- 13.1 Types of Solutions
- 13.2 Solution Concentration
- 13.3 Intermolecular Forces and the Solution Process
- 13.4 Solution Formation and Equilibrium
- 13.5 Solubilities of Gases