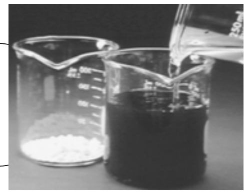
Chapter 11

Solutions and Their Properties



1

Solutions

- Homogeneous mixtures:
  - Solutions – ions or molecules (small particles)
  - Colloids – larger particles but still uniform (milk, fog)

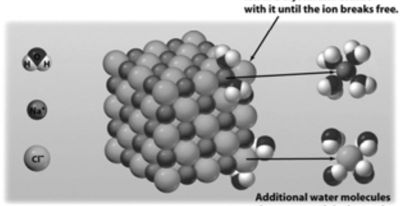
TABLE 11.1 Some Different Kinds of Solutions

Kind of Solution	Example
Gas in gas	Air (O_2N_2), Ar, and other gases)
Gas in liquid	Carbonated water (CO_2in water)
Gas in solid	H_2 in palladium metal
Liquid in liquid	Gasoline (mixture of hydrocarbons)
Liquid in solid	Dental amalgam (mercury in silver)
Solid in liquid	Seawater (NaCl and other salts in water)
Solid in solid	Metal alloys, such as sterling silver (92.5% Ag, 7.5% Cu)

The Solution Process

- During dissolution, some forces are broken and new forces are created

Water molecules surround an accessible edge or corner ion in a crystal and collide with it until the ion breaks free.



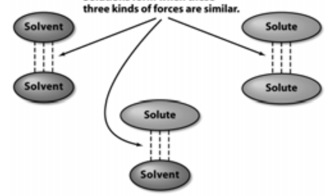
Additional water molecules then surround the ion and stabilize it by means of ion–dipole attractions.

3

The Solution Process

- Break up solvent-solvent attractions (endo.)
- Break up solute-solute attractions (endo.)
- Form solvent-solute attractions (exo.)
- $\Delta H_{soln} = \Delta H_1 + \Delta H_2 + \Delta H_3$

Solutions form when these three kinds of forces are similar.



4

Ways of Expressing Concentration

- Variety of units
  - Most commonly used is M (molarity)
  - Also molality, mole fraction, ppm, and Normality
- Qualitative terms relating to solubility
  - insoluble, slightly soluble, soluble, very soluble
- Other comparative terms:
  - dilute, concentrated (solids in liquids)
  - miscible, immiscible, partially miscible (liquids in liquids)

5

Concentration Units

- Molarity
  - <u>Molarity</u> = moles solute / liter solution = mol/L
  - Depends on temperature; density of liquids changes with temperature
  - Molarity:
  - Ex: 5.00 g NaCl in 0.251 L water
  - Ans: 0.341 M NaCl
- Mole fraction (X):
  - <u>Mole Fraction</u> = mole A / (mole A + mole B)
  - Ex: 5.00 g NaCl in 251 mL water
  - Ans: 0.00611 NaCl; 0.995 water

6

Concentration Units

- Mass Percent
  - Mass Percent = (mass of solute / mass of solution) x 100%
  - Ex: 5.00 g of NaCl in 251 mL H_2O (d_{H2O} = 0.9982 g/mL)
  - Ans: 2.0 % NaCl
- Molality
  - molality = moles solute / kilograms solvent = mol/kg
  - Independent of temperature because masses do not change with temperature (d_{H2O} = 0.9982 g/mL)
  - Ex: 5.00 g NaCl in 251 mL water
  - Ans: 0.340 m NaCl

Concentration Units

TABLE 11.3 A Comparison of Various Concentration Units

Name	Units	Advantages	Disadvantages
Molarity (M)	mol solute / L solution	Useful in stoichiometry; measure by volume	Temperature-dependent; must know density to find solvent mass
Mole fraction (*X*)	none	Temperature-independent; useful in special applications	Measure by mass; must know density to convert to molarity
Mass %	%	Temperature-independent; useful for small amounts	Measure by mass; must know density to convert to molarity
Molality (*m*)	mol solute / kg solvent	Temperature-independent; useful in special applications	Measure by mass; must know density to convert to molarity

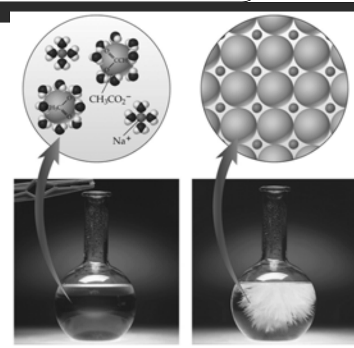
Table 11-3 Chemistry, 5/e

- Worked Ex. 11.4; Problems 11.6, 11.7

Types of Solutions

- ***Unsaturated solution***: contains less solute than it has the capacity to dissolve
- ***Saturated solution***: contains the maximum amount of solute that will dissolve in a given solvent at a specific temperature
- ***Supersaturated solution***: contains more solute than is present in a saturated solution
- ***Crystallization***: process in which a dissolved solute comes out of solution and forms crystals

Supersaturated Solution



Acetate

Movie

Like Dissolves Like

- It takes 2000 mL of H_2O to dissolve 1 mL of CCl_4
- It takes 50 mL of H_2O to dissolve 1 mL of CH_2Cl_2
- "Like" refers to the polarity of substances:
  - Polar substances will dissolve in polar solvents
  - Nonpolar substances will dissolve in nonpolar solvents
  - Polar substances WILL NOT readily dissolve in nonpolar solvents (and vice versa)

Solid Solubility and Temperature

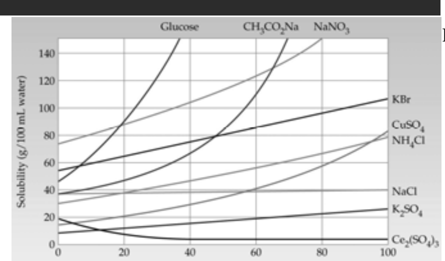
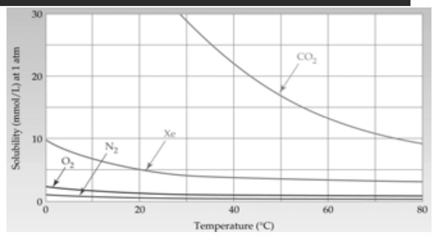


Figure 11.6

- Solubility of ionic compounds in water generally increases with higher water temps

Effect of Temp on Gas Solubility



- The solubility of gases in water decreases with increasing temperature. **Why?**
- Solubility goes to 0 at boiling point of water.

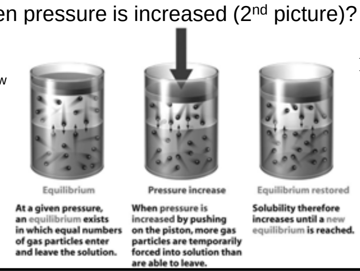
13

Effect of Pressure on Gas Solubility

- Strong effect only for **gases** dissolved in liquids.
- What happens to the amount of dissolved solute when pressure is increased (2[nd] picture)?

Henry's Law

Figure 11.8



14

Effect of Pressure on Solubility

- ***Henry's Law***: concentration (solubility) of a gas in a liquid is proportional to the pressure of the gas over the solution
- Why does a soft drink fizz when opened?

Henrys Law
Diet Coke

15

Colligative Properties

- ***Colligative properties***: depend only on the **number of solute particles** in solution and not on the nature of the solute particles. The particles may be covalent molecules or ionic compounds. (We'll only deal with covalent molecules.)
- Colligative means "depending on the collection"
  - Examples: vapor pressure
    boiling point
    freezing point
    osmosis / osmotic pressure

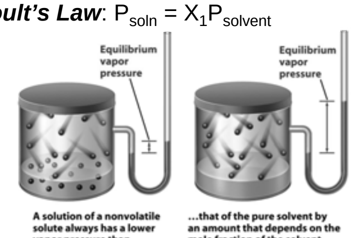
16

Vapor Pressure Lowering

P_{vap} liquid

P_{vap} solution

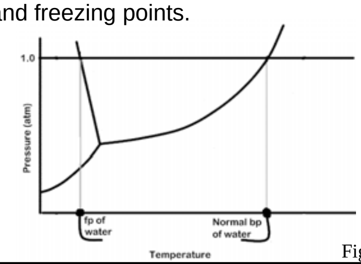
- Adding a solute to a solvent lowers the P_{vap}
- P_{vap} of a solution < P_{vap} of a pure solvent
- ***Raoult's Law***: $P_{soln} = X_1 P_{solvent}$



17

B. P. Elevation/F. P. Depression

- Phase diagrams can be used to see how vapor pressure changes cause changes in boiling and freezing points.



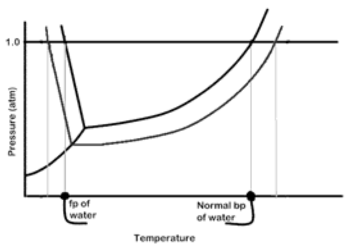
Freezing pure water

Figure 11.12

18

B. P. Elevation/F. P. Depression

- Lower vapor pressure (red lines)



B.P. Elevation/F.P. Depression

- Changes in boiling/freezing points are directly proportional to the number of solute particles
- Equations that govern these effects:
  $\Delta T_b = K_b\ m$ $\Delta T_f = K_f\ m$
  - K_b and K_f are based on the **solvent**
  - m = molality = moles solute / kg solvent
- Calculate molality: 62.345 g of vinyl chloride (CH_2CHCl, MM = 62.494 g/mol) is added to 1264 g chloroform. Calculate ΔT_b and ΔT_f.
- What's the solute? What's the solvent?

20

B.P. Elevation/F.P. Depression

TABLE 11.4 Molal Boiling-Point-Elevation Constants (K_b) and Molal Freezing-Point-Depression Constants (K_f) for Some Common Substances

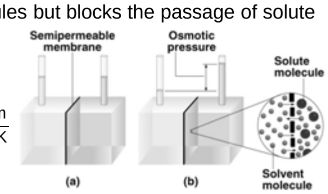
Substance	K_b [(°C · kg)/mol]	K_f [(°C · kg)/mol]
Benzene (C_6H_6)	2.53	5.12
Camphor ($C_{10}H_{16}O$)	5.95	37.7
Chloroform ($CHCl_3$)	3.63	4.70
Diethyl ether ($C_4H_{10}O$)	2.02	1.79
Ethyl alcohol (C_2H_6O)	1.22	1.99
Water (H_2O)	0.51	1.86

- K_b and K_f depend only on the **solvent** used
- Worked Ex. 11.11; Problems 11.18, 11.19

Osmotic Pressure

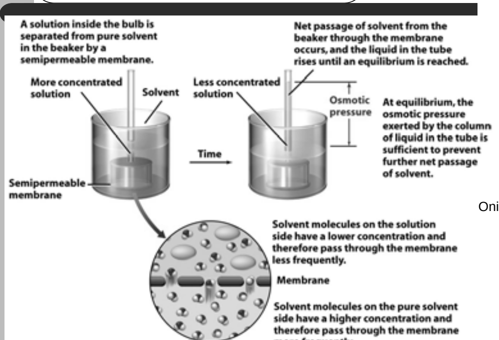
P_{os} molecular animation

- ***Osmosis***: selective passage of **solvent** molecules through a porous membrane from a dilute solution to a more concentrated one.
  - ***Semipermeable membrane***: allows the passage of solvent molecules but blocks the passage of solute molecules.
  - $\Pi = MRT$
  - M = molarity
  - R = 0.08206 $\frac{L\ atm}{mol\ K}$



22

Osmosis

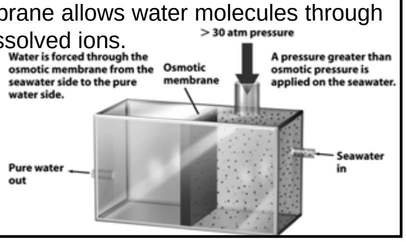


Onion 1M NaCl

Osmosis – pickling of cucumbers

Reverse Osmosis

- Uses high pressure to force water from a more concentrated solution to a less concentrated one through a semipermeable membrane. The membrane allows water molecules through but not dissolved ions.



What is Chemistry?

- On your note card, write your name at the top and numbers 1 - 4 down the left side. When each word is shown below, write the first thing that comes to mind.
- 1) Chemistry
- 2) Chemicals
- 3) Science
- 4) Experiments

26