Chapter 16
"Solutions"

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Section 16.1
Properties of Solutions

- OBJECTIVES:
  - Identify the factors that determine the **rate** at which a solute dissolves.

Section 16.1
Properties of Solutions

- OBJECTIVES:
  - Identify the units usually used to express the solubility of a solute.

Section 16.1
Properties of Solutions

- OBJECTIVES:
  - Identify the factors that determine the mass of solute that will dissolve in a given mass of solvent.

Solution formation

- The "nature" (polarity or composition) of the solute and the solvent will determine…
  - Whether a substance *will dissolve*
  - *How much* will dissolve
- Factors determining **rate** of solvation
  - stirring (agitation)
  - surface area the dissolving particles
  - temperature

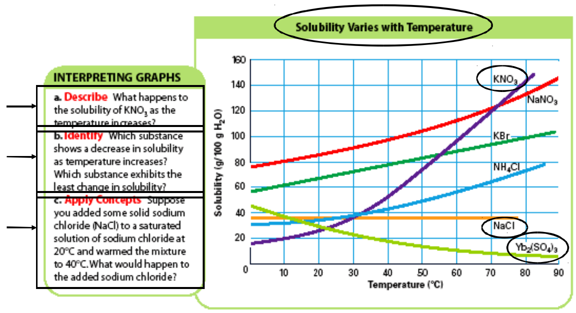
Making solutions

- In order to dissolve, the solvent molecules must come *in contact* with the solute.
- – 1. Stirring moves fresh solvent into contact with the solute.
- – 2. Smaller pieces increase the amount of surface area of the solute.
- ☐ - think of how fast a breath mint dissolves when you chew it

Temperature and Solutions

- 3. Higher temperature makes the molecules of the solvent move around faster and contact the solute harder and more often.
  - Speeds up dissolving.
- *Higher Temperature Also Usually* increases the amount that will dissolve (an exception is gases)

Figure 16.4 Interpreting Graphs - Page 474



Solids tend to dissolve best when:

- Heated
- Stirred
- Ground into smaller particles

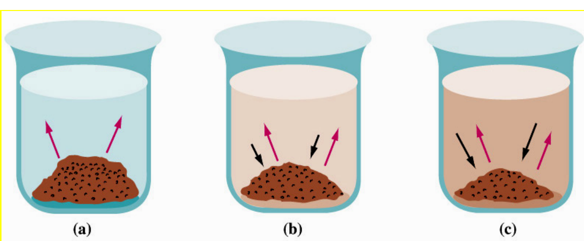
Gases tend to dissolve best when:

- The solution is cold
- Pressure is high

How Much?

- Solubility- is the maximum amount of substance that will dissolve at a specific temperature (the units for solubility are: g solute/100 g solvent)
- Saturated solution - Contains the *maximum* amount of solute dissolved. NaCl = 36.0 g/100 mL water
- Unsaturated solution - Can still dissolve more solute (for example 28.0 g NaCl/100 mL)
- Supersaturated - solution that is holding more than it theoretically can; a "seed crystal" will make it come out; Fig. 16.6, page 475

Saturation and Equilibrium



Solute is dissolving | More solute is dissolving, but some is crystallizing | Saturation equilibrium established

Supersaturated Example

- Ever heard of "seeding" the clouds to make them produce rain?
- Clouds - mass of air supersaturated with water vapor
- Silver Iodide (AgI) crystals are dusted into the cloud as a "seed"
- The AgI attracts the water, forming droplets that attract others

Liquids

- Miscible means that two liquids can dissolve in each other
  - water and antifreeze
  - water and ethanol
- Partially miscible- slightly
  - water and ether
- Immiscible means they can't
  - oil and vinegar

Solubility?

- For solids in liquids, as the temperature goes up-the solubility usually goes up (Fig. 16.4, p.474)
- For gases in a liquid, the effect is the opposite of solids in liquids
  - As the temperature goes up, gas solubility goes down
  - Think of boiling water bubbling?
  - Thermal pollution may result from industry using water for cooling

Gases in liquids...

- Henry's Law - says the solubility of a gas in a liquid is directly proportional to the pressure of the gas *above the liquid*
  - think of a bottle of soda pop, removing the lid releases pressure
- Equation: $\frac{S_1}{P_1} = \frac{S_2}{P_2}$

☐Sample 16.1, page 477

Calculating the Solubility of a Gas

- If the solubility of gas in water is 0.77g/L at 3.5 atm of pressure, what is its solubility (in g/L) at 1.0 atm of pressure?
- The solubility of a gas in water is 0.16g/L at 104kPa. What is the solubility when the pressure of the gas is increased to 288kPa?
- A gas has a solubility in water of 3.6g/L at a pressure of 1.0 atm. What pressure is needed to produce an aqueous solution containing 9.5g/L of the same gas?

Section 16.2 Concentration of Solutions

- OBJECTIVES:
  - Solve problems involving the molarity of a solution.

Section 16.2 Concentration of Solutions

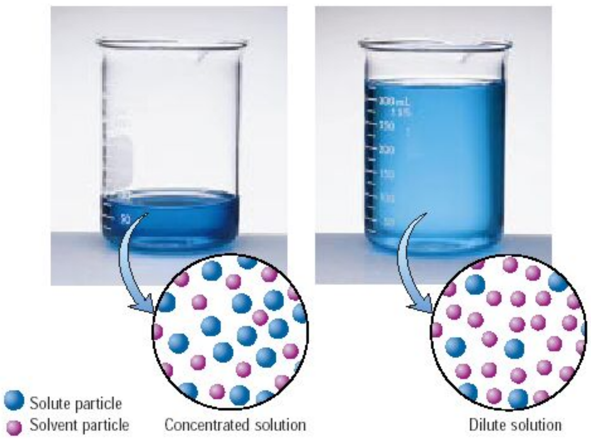
- OBJECTIVES:
  - Describe the effect of dilution on the total moles of solute in solution.

Section 16.2
Concentration of Solutions

- OBJECTIVES:
  - Define percent by volume and percent by mass solutions.

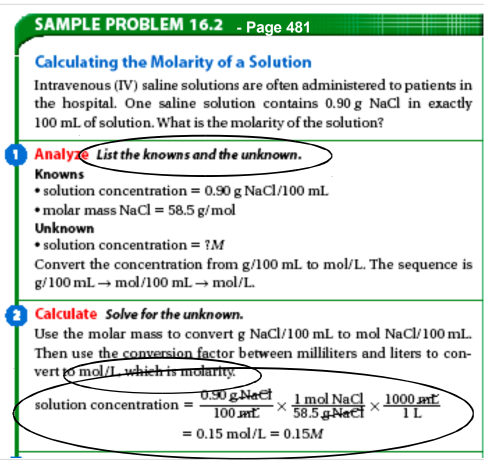
Concentration is...

- a measure of the amount of solute dissolved in a given quantity of solvent
- A concentrated solution has a large amount of solute
- A dilute solution has a small amount of solute
  - These are *qualitative* descriptions
- But, there are ways to express solution concentration *quantitatively*



Molarity

- Molarity = $\frac{\text{moles of solute}}{\text{liters of solution}}$
  - Abbreviated with a capital M, such as 6.0 M
- This is the most widely used concentration unit used in chemistry.



SAMPLE PROBLEM 16.2 - Page 481

Calculating the Molarity of a Solution

Intravenous (IV) saline solutions are often administered to patients in the hospital. One saline solution contains 0.90 g NaCl in exactly 100 mL of solution. What is the molarity of the solution?

1 **Analyze** *List the knowns and the unknown.*

Knowns
- solution concentration = 0.90 g NaCl/100 mL
- molar mass NaCl = 58.5 g/mol

Unknown
- solution concentration = ?*M*

Convert the concentration from g/100 mL to mol/L. The sequence is g/100 mL → mol/100 mL → mol/L.

2 **Calculate** *Solve for the unknown.*

Use the molar mass to convert g NaCl/100 mL to mol NaCl/100 mL. Then use the conversion factor between milliliters and liters to convert to mol/L, which is molarity.

$$\text{solution concentration} = \frac{0.90\text{ g NaCl}}{100\text{ mL}} \times \frac{1\text{ mol NaCl}}{58.5\text{ g NaCl}} \times \frac{1000\text{ mL}}{1\text{ L}}$$
$$= 0.15\text{ mol/L} = 0.15M$$

Calculating the Molarity of a Solution

- A solution has a volume of 2.0L and contains 36.0g of glucose ($C_6H_{12}O_6$). If the molar mas of glucose is 180 g/mol, what is the molarity of the solution?
- A solution has a volume of 250mL and contains 0.70 mol NaCl. What is its molarity?

Making solutions

- Pour in a *small amount* of the solvent, maybe about one-half
- Then add the pre-massed solute (and mix by swirling to dissolve it)
- Carefully fill to final volume.
  - Fig. 16.8, page 481
- Can also solve: moles = M x L
- Sample Problem 16.3, page 482

Finding the Moles of Solute in a Solution

- Household laundry bleach is a dilute aqueous solution of sodium hypochlorite (NaClO). How many moles of solute are present in 1.5L of 0.70M NaClO?
- How many moles of ammonium nitrate are in 335mL of 0.425M NH_4NO_3?
- How many moles of solute are in 250mL of 2.0M $CaCl_2$? How many grams of $CaCl_2$ is this?

Dilution

- Adding water to a solution will reduce the number of moles of solute *per unit volume*
  - but the overall number of moles remains the same!
- Think of taking an aspirin with a small glass of water vs. a large glass of water
  - You still have one aspirin in your body, regardless of the amount of water you drank, but a larger amount of water makes it more diluted.

Dilution

- The number of moles of solute in solution doesn't change if you add more solvent!
- The # moles before = the # moles after
- Formula for dilution: $M_1 \times V_1 = M_2 \times V_2$
- M_1 and V_1 are the starting concentration and volume; M_2 and V_2 are the final concentration and volume.
- Stock solutions are pre-made solutions to known Molarity. Sample 16.4, p.484

Preparing a Dilute Solution

- How many milliliters of aqueous 2.00M $MgSO_4$ solution must be diluted with water to prepare 100.0mL of aqueous 0.400M $MgSO_4$?
- How many milliliters of a solution of 4.00M KI are needed to prepare 250.0mL of 0.760M KI?
- How could you prepare 250mL of 0.20M NaCl using only a solution of 1.0M NaCl and water?

Percent solutions can be expressed by a) volume or b) mass

- Percent means parts per 100, so
- Percent by volume: $= \frac{\text{Volume of solute}}{\text{Volume of solution}} \times 100\%$
- indicated %(v/v)
- Sample Problem 16.5, page 485

Calculating Percent (Volume/Volume)

- What is the percent by volume of ethanol (C_2H_6O) in the final solution when 85mL of ethanol is diluted to a volume of 250mL of water?
- If 10mL of propanone (C_3H_6O) is diluted with water to a total solution volume of 200mL, what is the percent by volume of propanone in the solution?
- A bottle of the antiseptic hydrogen peroxide (H_2O_2) is labeled 3.0% (v/v). How many mL H_2O_2 are in a 400.0mL bottle of this solution ?

Percent solutions

- Percent by mass: = $\frac{\text{Mass of solute(g)}}{\text{Volume of solution (mL)}} \times 100\%$

  Indicated %(m/v)
- More commonly used
- 4.8 g of NaCl are dissolved in 82 mL of solution. What is the percent of the solution?
- How many grams of salt are there in 52 mL of a 6.3 % solution?

Section 16.3 Colligative Properties of Solutions

- OBJECTIVES:
  - Identify three colligative properties of solutions.

Section 16.3 Colligative Properties of Solutions

- OBJECTIVES:
  - Explain why the vapor pressure, freezing point, and boiling point of a solution differ from those properties of the pure solvent.

Colligative Properties

-Depend only on the ***number*** of dissolved particles

-Not on what ***kind*** of particle

-Three important colligative properties are:

- Vapor pressure lowering
- Boiling point elevation
- Freezing point lowered

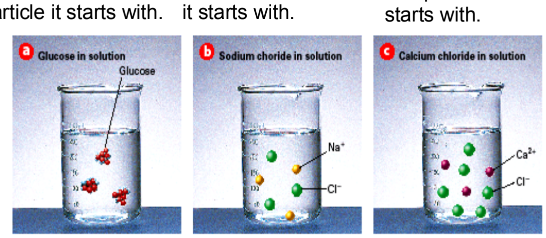
Figure 16.14 Particle Concentrations in Solutions - Page 488

Colligative Properties

Glucose will only have one particle in solution for each one particle it starts with.

NaCl will have two particles in solution for each one particle it starts with.

$CaCl_2$ will have three particles in solution for each one particle it starts with.



Vapor Pressure is lowered

- The bonds between molecules keep molecules from escaping.
- In a solution, some of the solvent is busy keeping the solute dissolved.
- Lowers the vapor pressure
- Electrolytes form ions when they are dissolved, making more pieces.
- $NaCl \rightarrow Na^{+} + Cl^{-}$ (= 2 pieces)
- More pieces = bigger effect

Boiling Point is Elevated

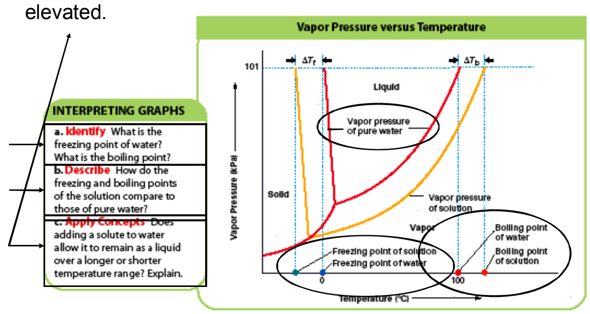
- The vapor pressure determines the boiling point.
- Lower vapor pressure means you need a higher temperature to get it to equal atmospheric pressure
- Salt water boils above 100ºC
- The number of dissolved particles determines how much, as well as the solvent itself.

Freezing Point is Lowered

- Solids form when molecules make an orderly pattern - crystals
- The solute molecules break up the orderly pattern.
  - Makes the freezing point lower.
  - Salt water freezes below 0ºC
- How much lower depends on the amount of solute dissolved.

Figure 16.20 Interpreting Graphs - Page 494

The addition of a solute would allow a larger temperature range, since freezing point is lowered and boiling point is elevated.



Section 16.4 Calculations Involving Colligative Properties

- OBJECTIVES:
  - Solve problems related to the molality and mole fraction of a solution.

Section 16.4 Calculations Involving Colligative Properties

- OBJECTIVES:
  - Describe how freezing point depression and boiling point elevation are related to molality.

Molality (abbreviated m)

- a new unit for concentration
- $m = \dfrac{\text{Moles of solute}}{\text{kilogram of solvent}}$
- $m = \dfrac{\text{Moles of solute}}{\text{1000 g of solvent}}$
- Sample Problem 16.6, p. 492

Mole fraction

- This is another way to express concentration
- It is the ratio of moles of solute to total number of moles of solute plus solvent (Fig. 18-19, p.522)

$$X = \frac{n_a}{n_a + n_b}$$

Sample 16.7, page 493

Freezing Point Depression

- The size of the change in freezing point is also determined by molality.
- $\Delta T_f = -K_f \times m \times n$
- ΔT_f is the change in freezing point
- K_f is a constant determined by the solvent (Table 16.2, page 494).
- n is the number of pieces it falls into when it dissolves.

SAMPLE PROBLEM 16.8 - Page 495

Calculating the Freezing-Point Depression of a Solution

Antifreeze protects a car from freezing. It also protects it from overheating. Calculate the freezing-point depression and the freezing point of a solution containing 100 g of ethylene glycol ($C_2H_6O_2$) antifreeze in 0.500 kg of water.

1 Analyze *List the knowns and the unknown.*

Knowns	Unknown
• mass of solute = 100 g $C_2H_6O_2$	• ΔT_f = °C
• mass of solution = 0.500 kg H_2O	• freezing point = ?°C
• K_f for H_2O = 1.86°C/m	
• $\Delta T_f = K_f \times m$	

Calculate the number of moles of solute and the molality. Then calculate the freezing-point depression and freezing point.

2 Calculate *Solve for the unknown.*

$$\text{moles } C_2H_6O_2 = 100\ \text{g}\ C_2H_6O_2 \times \frac{1\ \text{mol}}{62.0\ \text{g}\ C_2H_6O_2} = 1.61\ \text{mol}$$

$$m = \frac{\text{mol solute}}{\text{kg solvent}} = \frac{1.61\ \text{mol}}{0.500\ \text{kg}} = 3.22m$$

$$\Delta T_f = K_f \times m = 1.86°C/m \times 3.22m = 5.99°C$$

The freezing point of the solution is 0.00°C − 5.99°C = −5.99°C.

Boiling Point Elevation

- The size of the change in boiling point is determined by the molality.
- $\Delta T_b = K_b \times m \times n$
- ΔT_b is the change in the boiling point
- K_b is a constant determined by the solvent (Table 16.3, page 495).
- n is the number of pieces it falls into when it dissolves.
- Sample Problem 16.9, page 496

Key Equations

- Note the key equations on page 498 to solve problems in this chapter.