Properties of Solutions

Chapter 13

Objectives

Following your study of this chapter, you should be able to

1. define the terms; *solution*, *solute*, *solvent*, *dissolution* and *concentration*.
2. distinguish between the physical/chemical changes which occur when sodium chloride is added to water and when sodium metal is added to water.
3. list and give examples of the phase combinations from which a solution can be formed.
4. describe the macroscopic observations when pairs of liquids are mixed together.
5. list a set of rules for predicting whether a molecule is polar or nonpolar.
6. describe the intermolecular attractive forces; dipole-dipole, hydrogen-bonding and dispersion forces.
7. describe the interactions responsible for determining whether a particular solute-solvent pair will form a homogeneous mixture or a heterogeneous mixture.
8. describe how an energy analysis of the attractive interactions lead to exothermic or endothermic enthalpies ($\Delta H^\circ_{solution}$) of solution.
9. define the terms; *solubility*, *unsaturated*, *saturated* and *supersaturated*.
10. list the important criteria for predicting whether a mixture will be homogeneous or heterogeneous when mixing a solid and a liquid.
11. define the term *lattice energy* and explain its importance in the enthalpy of solution.
12. list the important criteria for predicting whether a mixture will be homogeneous or heterogeneous when mixing a gas and a liquid.
13. define the concentration terms; *weight percent*, *mole fraction*, *molarity*, and *molality* and use these concentration expressions to determine the concentration of any homogeneous mixture.
14. define the term *colligative property* and list those physical properties of a solution which can be classified as colligative properties.
15. explain how the vapor pressure of a liquid solvent in a solution is affected by the presence of a solute.
16. write the mathematical equation which relates the vapor pressure of the solution to the concentration of the solute and the vapor pressure of the solvent.
17. explain how and why the freezing point and the boiling point of a liquid are affected by the addition of a nonvolatile solute.
18. write and use the mathematical equation that describes the dependence of the freezing point or boiling point on the concentration of solution.
19. define the terms *semipermeable membrane*, *osmosis* and *osmotic pressure*.
20. list some examples and several characteristic properties of a colloid.

1. Define the following terms:

solution

solute

solvent

dissolution

concentration

2. Based on the BCE describe what happens when the following pairs of liquids are mixed together.

   a) water and hexane

   b) hexane and carbon tetrachloride

   c) water and ethanol

3 List the set of rules which can be used to predict the polarity of a covalent molecule. **(Review: See Exercises 9 and 10 in Chapter 9 of the Lectureguide)**

4. Briefly describe each of the following types of intermolecular attractive forces. Sketch the orientations of molecules and/or ions involved in the following intermolecular attractive forces. Include at least one specific example where each attractive force is important. For each one, tell what causes the force and describe its strength relative to the others. **(Review: See Exercises 10 and 11 in Chapter 11 of the Lectureguide.)**

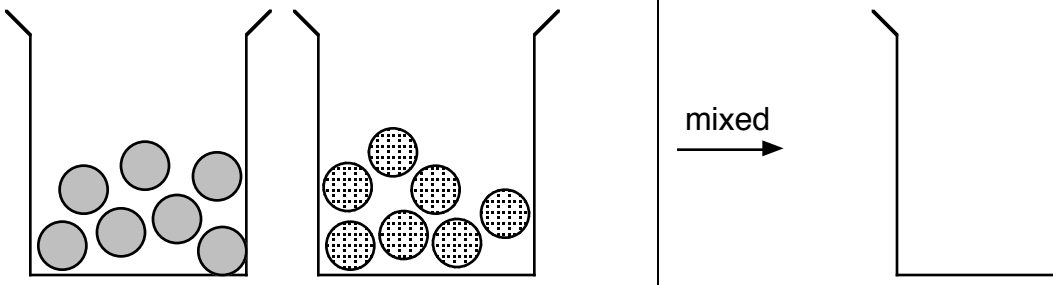
dipole-dipole forces

London dispersion forces

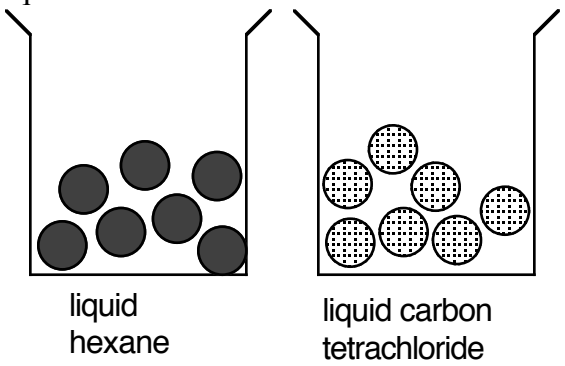
hydrogen-bonding forces

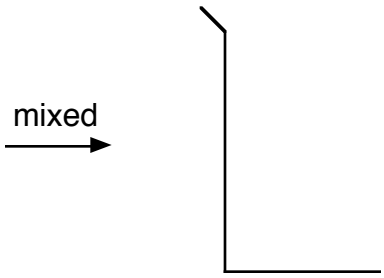
5. The three attractive interactions which are important in solution formation are; solute-solute interactions, solvent-solvent interactions, and solute-solvent interactions. Define each of these interactions and describe their importance in determining whether a particular solute-solvent pair will form a homogeneous mixture or a heterogeneous mixture.

Shown below are two beakers. One contains liquid water and the other contains liquid carbon tetrachloride. For simplicity a circle is used to represent the molecule. Complete the beaker on the right to illustrate the result of mixing the two liquids.



Shown below are two beakers. One contains liquid hexane and the other contains liquid carbon tetrachloride. For simplicity a circle is used to represent the molecule. Complete the beaker on the right to illustrate the result of mixing the two liquids.





6a. Define the following terms;

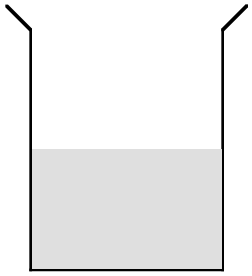
solubility

unsaturated solution

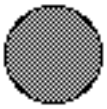
saturated solution

supersaturated solution

b. Given that the beaker to the right contains an aqueous solution of NaCl, describe a simple test to determine whether the solution is unsaturated, saturated or supersaturated. What would you expect to happen during the test if the solution were unsaturated? saturated? supersaturated?



7a. Given the representations below, sketch the orientations of a chloride ion and a several water molecules and a sodium ion and several water molecules to illustrate the ion-dipole interaction.


chloride ion


sodium ion


water

b) Briefly describe ion-dipole intermolecular attractive forces that occur when an ionic solid dissolves in water. Indicate what causes the attractive force and describe how the strength depends on the charge and the size of the ion.

8. Define the term *lattice energy* and explain its importance in the enthalpy of solution.

9a. Define the concentration terms;

weight percent

mole fraction

molarity

molality

b. Calculate the molality and mol fraction of HCl for a solution which is 37.1 % HCl by weight (mass).

Ans: 16.2 *m*

c. If the density of the solution described in b. is 1.18 g/mL, calculate the molarity of the solution.

Ans: 12.0 M

d. Calculate the weight percent NaCl in a solution which is 0.632 molal.

Ans: 3.57 %

e. A solution of ethylene glycol, $C_2H_4(OH)_2$, which is 6.77 molar has a density of 1.05 g/mL. Calculate the mole fraction of ethylene glycol in the solution.

Ans: 0.162

10. Define the term *colligative property* and list those physical properties of a solution which can be classified as colligative properties.

11. Illustrate and explain how the presence of a nonvolatile solute affects the vapor pressure of a liquid.

12. Write Raoult's law and define each term.

a. Calculate the expected vapor pressure at 25 °C for a solution prepared by dissolving 97.4 g of common table sugar (sucrose, MM = 342 $\frac{g}{mol}$) in 453 mL of water.

Ans: 23.5 mmHg

b. A solution was prepared by adding 20.0 g of urea to 125 g of water at 25 °C, a temperature at which pure water has a vapor pressure of 23.76 mm of Hg. The observed vapor pressure of the solution was found to be 22.67 mm of Hg. Calculate the molecular weight of urea.

Ans: 59 $\frac{\mathbf{g}}{\mathbf{mol}}$

c. Show the derivation of a mathematical relationship for the vapor pressure lowering ($P^{\circ}_{solvent} - P_{solution}$) of a liquid following the addition of a nonvolatile solute.

13a. Write the general mathematical relation which describes the dependence of the freezing point or boiling point on the concentration of solution.

b. Calculate the freezing point and boiling point of a solution prepared by mixing 6.00 g of $C_6H_{12}O_6$ with 35.0 g of H_2O.

Ans: T_{fp} = –1.77 ˚C : T_{bp} = 100.486 ˚C

c. A solution containing a nonelectrolyte dissolved in water has a boiling point of 100.305 ˚C. Calculate the freezing point of the same solution.

Ans: T_{fp} = -1.11 ˚C

d. What is the molecular mass of nicotine if 5.04 grams of this compound changes the freezing point of 90.0 g of water by 0.647 ˚C?

Ans: 161 $\frac{\mathbf{g}}{\mathbf{mol}}$

e. Calculate the freezing point and the boiling point of a saturated solution of Li_2CO_3. The solubility of lithium carbonate is 0.72 g per 100 g of water at 100 ˚C.

Ans: T_{fp} = –0.544 ˚C : T_{bp} = 100.149 ˚C

f. 2.57 g of an ionic compound with the formula KX are dissolved in 120 g of water. The freezing point of the solution was lowered by 1.37 ˚C. Determine the formula weight of X.

Ans: 19 $\frac{\mathbf{g}}{\mathbf{mol}}$