

Chapter 13

Properties of Solutions

Section 13.1 The Solution Process

SOLVENT - any substance that has other substances dissolved in it (often a liquid)

ie. The dissolving medium

- often the substance present in the largest amount.

SOLUTE - the dissolved substances in a solution (often solids) ie. The dissolving particles.

SOLUTION – a homogeneous mixture (solvent and solute). It is formed when one substance disperses uniformly throughout another.

- ▶ a major factor to determine whether a solution forms is the relative strengths of intermolecular forces among the solute and solvent particles. ie the extent of dissolving depends on the magnitude of the solute-solvent, solute-solute, and solvent-solvent interactions involved in the solution process.
- ▶ can exist in many concentrations. **CONCENTRATED SOLUTIONS** have a higher proportion of solute to solvent than **DILUTE SOLUTIONS**.
- ▶ may be a gas, liquid, or solid. A solid solution of metals is called an **ALLOY**.
- ▶ **AQUEOUS SOLUTION** - a solution in which water is the solvent

The process of dissolving occurs differently for ionic and molecular compounds.

1. Process of an ionic compound dissolving in water.

When an ionic compound, such as NaCl, enters water the water molecules begin to collide with it. The ion-dipole interaction that occurs between the water molecule and the ions is strong enough to break the ionic bond. When the water molecules have surrounded the ions (ie the ions have been **HYDRATED**) dissolving has occurred.

2. Process of a molecular compound dissolving in water.

When a molecular compound, such as sugar, enters water the water molecules begin to collide with it. The sugar molecules stay together as a unit and only separate from each other by breaking the intermolecular attractions rather than the covalent bonds. Dissolving has occurred when the molecules are hydrated. A dipole interaction has occurred between the sugar and the water.

Some ionic compounds have stronger inward attractive forces than those exerted on it by the water, so these compounds are said to be INSOLUBLE in water eg CaCO_3 and BaSO_4 .

'Like Dissolves Like' = compounds with certain characteristics will dissolve other compounds with similar characteristics.

Polar dissolves polar/ionic

Ionic dissolves ionic

Non-polar dissolves non-polar

So since water is polar it can dissolve both, polar and ionic compounds.

Water can dissolve polar such as sugar

Water can dissolve ionic such as salt

Water can NOT dissolve non-polar such as oil

Subsection: Solution Formation, Spontaneity, and Entropy p. 531

SPONTANEOUS REACTION – a reaction that occurs without any extra input of energy from outside the system.

Spontaneity depends on two factors:

1. Energy

- processes tend to be spontaneous if the energy content of the system decreases
- endothermic = tends to be non-spontaneous
- exothermic = tends to be spontaneous

2. Entropy

- ENTROPY = the degree of randomness (ie disorder) in a system
- processes tend to be spontaneous if the entropy of the system increase

Section 13.2 Saturated Solutions and Solubility

SOLUBILITY - the mass of solute that dissolves in a given quantity of solvent at a certain temperature

- depends on the forces of attraction between the particles\

SATURATED SOLUTION

- a solution in which NO more of a particular solute can be dissolved at a specific temperature.

UNSATURATED SOLUTION

- a solution which contains LESS of a particular solute than can be dissolved at a specific temperature.

SUPERSATURATED SOLUTION

- a solution which contains MORE of a particular solute than can theoretically dissolve at a specific temperature.

Solid and liquid solutes can be described as

- INSOLUBLE when < 0.1 gram per 100ml of solvent dissolves
- SOLUBLE when > 1 gram per 100ml of solvent dissolves

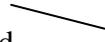
Section 13.3 Factors Affecting Solubility

Three factors affect solubility

1. Nature of molecule/ Solute-Solvent Interactions

- Smaller particles are usually more soluble than larger molecules
- The very nature of a solute and solvent determines the forces between them. ('Like dissolves like' – substance with similar intermolecular attractive forces tend to be soluble in one another). The stronger the attraction between the solute and the solvent the greater the solubility
- MISCIBLE - liquids that can dissolve in each other in any proportion (ie either could be considered the solvent) eg water and ethanol
- IMMISCIBLE - liquids that do NOT readily dissolve in one another eg oil and water.

2. Pressure

-solid 
- liquid  No real effect

- gas - the solubility of a gas in any solvent is increased as the pressure over the solvent increases. (ie the higher the pressure the more gas that dissolves- Henry's Law)
{discuss pop, bends, and cracking knuckles p.252}

3. Temperature (Solubility Worksheet)

- solid → the solubility of most solids increases as the temperature increases (b/c energy is needed to break bonds and the higher temperature gives that energy)
- liquid → the solubility of liquids is not greatly affected by temperature
- gas → the solubility of gases decreases as the temperature increases (b/c at higher temperatures particles of gas move faster and can leave solution)
{discuss thermal pollution}

Added topic: From Section 4.1 on Electrolytes and Non-Electrolytes

- Compounds that conduct an electrical current in aqueous solution or the molten state are said to be ELECTROLYTES. Electrolytes may be strong or weak.
STRONG ELECTROLYTES are solutes (when in solution) that exist almost completely as ions. Eg. All soluble ionic compounds and strong acids.
WEAK ELECTROLYTES are solutes (when in solution) that are mostly in the form of molecules with only a small fraction in the form of ions. eg weak acids
- Compounds that DO NOT conduct an electrical current in aqueous solution or the molten state are said to be NON-ELECTROLYTES.

*** The more solute that exists as ions the stronger the electrolyte.

***You must break into ions in order to be an electrolyte.

{demo - using light bulb apparatus}

Section 13.4 Ways of Expressing Concentration

{We are adding in Molarity from section 4.5}

1) Molarity

Molarity (or molar concentration) is equal to the moles of solute in one litre of solution.

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution (in litres)}}$$

**Units can be expressed as M or mol/L

Refer to molarity worksheets for practice problems.

***Under the molarity section there is another type of math problem called DILUTION PROBLEMS. They need to be taught here, but they are not a type of concentration. $M_1 \times V_1 = M_2 \times V_2$

There are two ways to prepare a standard solution:

1. Dissolving a measured mass of solute in a certain volume of solution.
2. Diluting a solution of known concentration

$$M_1 \times V_1 = M_2 \times V_2$$

2) Mass Percentage, ppm, and ppb

$$\text{Mass Percentage of Compound} = \frac{\text{Mass of solute}}{\text{Total mass of Solution}} \times 100\%$$

eg. a 36% HCl solution contains 36-grams of HCl for each 100-ml of solution.

ppm and ppb

- use the same formula as mass percentage, but instead of multiplying by 100, you multiply ppm by 10^6 and ppb by 10^9 .

Eg. a solution that's concentration is 1 ppm contains 1-gram of solute for each million grams (10^6) of solution OR 1-mg of solute per 1-kg of solution.

SAMPLE EXERCISE 13.4 Calculation of Mass-Related Concentrations

(a) A solution is made by dissolving 13.5 g of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) in 0.100 kg of water. What is the mass percentage of solute in this solution? **(b)** A 2.5-g sample of groundwater was found to contain 5.4 μg of Zn^{2+} . What is the concentration of Zn^{2+} in parts per million?

PRACTICE EXERCISE

(a) calculate the mass percentage of NaCl in a solution containing 1.50 g of NaCl in 50.0 g of water. **(b)** A commercial bleaching solution contains 3.62 mass % sodium hypochlorite, NaOCl. What is the mass of NaOCl in a bottle containing 2.50 kg of bleaching solution?

Answers: (a) 2.91% (b) 90.5 g NaOCl

3) Mole Fraction

$$\text{Mole Fraction} = \frac{\text{moles of component}}{\text{total moles of all components}}$$

**Note: There are no units for mole fraction

The symbol X is commonly used for mole fraction, with a subscript to indicate the component of interest.

** Note: The sum of the mole fractions of all of the components of a solution must equal 1.

Sample Exercise 13.6 Calculation of Mole Fraction

An aqueous solution of hydrochloric acid contains 36% HCl by mass. Calculate the mole fraction of HCl in the solution.

Bonus Question: What is the mole fraction of water?

4) Molality

$$\text{Molality} = \frac{\text{moles of solute}}{\text{kg of solvent}}$$

SAMPLE EXERCISE 13.5 Calculation of Molality

A solution is made by dissolving 4.35 g of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) in 25.0 mL of water at 25°C . Calculate the molality of glucose in the solution. Water has a density of 1.00 g/mL.

PRACTICE EXERCISE

What is the molality of a solution made by dissolving 36.5 g of naphthalene (C_{10}H_8) in 425 g of toluene (C_7H_8)? *Answer: 0.670 m*

The following is a challenge question. Please work on it at home.

SAMPLE EXERCISE 13.7 Calculation of Molarity Using Density of the Solution

A solution with a density of 0.876 g/mL contains 5.0 g toluene (C_7H_8) and 225 g benzene. Calculate the molarity of the solution. *Answer: 0.21 M*