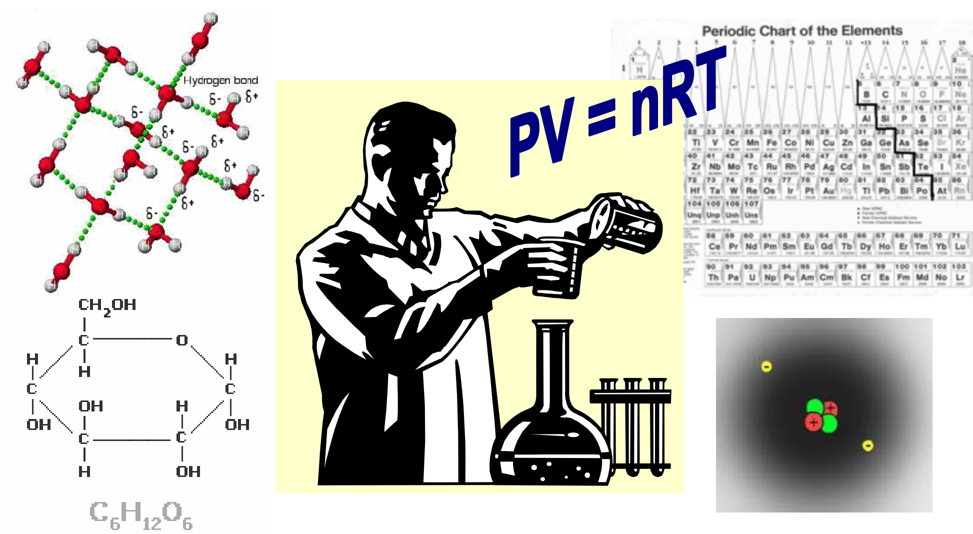
Project EASE

(Effective Alternative Secondary Education)

CHEMISTRY



MODULE 7

Solutions

BUREAU OF SECONDARY EDUCATION
Department of Education
DepEd Complex, Meralco Avenue
Pasig City

Module 7
Solutions

What this module is about

Many of the substances we deal with in daily life such as air, gasoline, vinegar, corn syrup, coconut oil, seawater, cooking gas, and stainless steel share common characteristics --- they are all solutions. Each of them is made up of more than one component, but each component is evenly distributed. Solutions of this kind are known as *homogenous solutions*.

In this module, you will learn more about solutions, their nature, properties and the ways of expressing their concentration. As you read the module, it will introduce you to the versatile world of solutions. Hopefully, you will learn to appreciate the importance of solutions not just in our life but in the world we live in.

To make the discussion easy for you, the module is divided into four lessons:

- **Lesson 1 – What Distinguishes Solutions from Non-Solutions?**
- **Lesson 2 – What Makes a Solute Dissolve Faster?**
- **Lesson 3 – How Much Solute Can Be Dissolved in a Solution?**
- **Lesson 4 – Why Do You Need to Study Solutions?**

What you are expected to learn

After going through this module, you should be able to:

1. identify the types of solutions;
2. describe the changes that occur in the dissolving process of solutions;
3. relate the changes that go with the dissolving process to energy changes and disorderliness;
4. differentiate saturated, unsaturated and supersaturated solutions;
5. identify the factors affecting solubility;
6. express concentration of solution in terms of percent composition, mole fraction, molarity, and molality ; and
7. appreciate the importance of solutions in our daily activities.

How to learn from this module

Here are some pointers to remember as you go through this module.

1. Read and follow the instructions carefully.
2. Answer the pretest first before reading the content of the module.
3. Take down notes and record points for clarification.
4. Always aim to get at least 70% of the total number of items given.
5. Be sure to answer the posttest at the end of the module.

What to do before (Pretest)

Take the pretest before proceeding to the lessons. Check your answers against the answer key at the end of the module.

I. Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. All of the following are solutions **EXCEPT**
   a. milk
   b. wine
   c. alloy
   d. coffee

2. All of the following affects the solubility of a solid in a liquid **EXCEPT**
   a. pressure
   b. stirring
   c. surface area
   d. temperature

3. A metal solution is called a(n)
   a. alloy
   b. colloid
   c. suspension
   d. electrolyte

4. Why is a solution considered homogenous?
   a. It is usually liquid.
   b. It contains a solute and solvent.
   c. It can be dilute or concentrated.
   d. Its components are distributed evenly in all proportions.

5. All of the following describes a solution **EXCEPT**
   a. clear
   b. homogenous
   c. cannot pass through filter paper
   d. can be separated by physical means

6. A solution that contains the maximum amount of dissolved solute is:
   a. saturated
   b. unsaturated
   c. concentrated
   d. supersaturated

7. The following substances are soluble in water **EXCEPT**
   a. oil
   b. salt
   c. sugar
   d. alcohol

8. What is the maximum amount of solute that can be dissolved in a fixed amount of solvent at a given temperature?
   a. dilution
   b. molarity
   c. solubility
   d. dissolution

9. What is the concentration of a solution expressed in moles of solute per kilogram solvent?
   a. molality
   b. molarity
   c. mole fraction
   d. percentage by weight

10. The pH of human saliva is 6.5. How would you describe the solution?
   a. basic
   b. acidic
   c. saturated
   d. supersaturated

II. True or False. Write the word **TRUE** if the statement is correct and **FALSE** if it is incorrect.

_________ 1. Solutions are homogenous.
_________ 2. Solutes can exist as solid, liquid or gas.
_________ 3. Water can dissolve anything that is why it is called the universal solvent.
_________ 4. When a liquid solute is dissolved in a liquid solvent they are said to be soluble to one another.
_________ 5. Solubility of solids, liquids and gas increases with increasing temperature.

Key to answers on page 25.

Lesson 1. What Distinguishes Solutions from Non-Solutions?

When you are preparing coffee in the morning, you are actually making a solution. It is considered a ***solution*** because it is a homogenous mixture of two or more substances evenly distributed in each other. The coffee and sugar that you mix in the hot water are the ***solutes*** or the substances dissolved, and the ***solvent*** is the hot water, the liquid material in which the solute has dissolved. These are the components of a solution. The solute can be in the form of solid, liquid, or gas.

To know more about the general properties of solutions, try to do Activity 1.1.

What you will do

Activity 1.1 Solutions vs. non-solutions

Materials:	Sand	Soy Sauce
	Glass of water	Spoon
	Salt	Bond papers

Procedure:

1. Add some sand to a glass of water and stir. To another glass of water, add some salt, stir and taste it. Observe the results. Which of the two set-ups dissolved the solute completely? ______________________________

2. Leave the two set-ups for five minutes and take note of the results. Did the sand dissolve and form a solution? How about the salt? ______________________________

3. Prepare another set-up by mixing soy sauce with water. Stir and taste it. Compare the third set-up with the two previous set-ups by observing the three samples in a transparent glass under sunlight, or you may use a flashlight and allow light to pass through the samples. Which of the three set-ups form a clear solution? (Note: A *clear solution* is not necessarily colorless, but is transparent to light.) ____________________

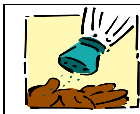
4. Add more salt, sand, or soy sauce to each corresponding set-up and stir. For the second time, taste the salt and soy sauce set-ups. Are they saltier than the first taste test? ______________________________

5. Get a piece of bond paper and fold it to form a cone. Allow the three set-ups to pass through this improvised filter paper. Can they be separated by physical means?
____

Analysis:

1. Identify the solute and solvent in each of the three set-ups.
2. Which of the three set-ups forms a solution? Why?______________________________
____
3. What property of solution is evident in Step 1? 2? 3? 4? 5? Explain.
____
____

You have just explored the different properties that distinguish a solution from a non-solution. There are several ways of classifying solutions. It can be based on the phase of the solution and according to the relative amounts of the components of the solution.

 **Did you know?**

The oldest way of making salts is through solar evaporation. The collected sea water is made to evaporate under the sun and is allowed to crystallize to form rock salts in the process of crystallization. Crystallization is the process in which dissolved solute comes out of the solution and forms crystals. Crystals form through crystallization in warm solutions that have cooled or evaporated. These rock salts are added to food to give it a salty taste.

In terms of phase, a solution can be classified as gaseous, solid or liquid. Air is an example of a ***gaseous solution***. It is the combination of nitrogen, oxygen, and carbon dioxide gases. Certain alloys such as brass (solution of zinc and copper) and coinage silver (solution of copper and silver) are examples of ***solid solutions***. Seawater and blood are examples of ***liquid solutions***. Can you think of other examples of gaseous, solid or liquid solutions that you encounter in your daily activities?

Solutions are also classified as dilute and concentrated based on the relative amounts of components of the solution. When the solute is present in small amounts, the solution is said to be ***dilute***. But when the solute is present in considerably significant amounts, the solution is said to be ***concentrated***.

However, solutions must not be confused with ***suspensions***. A basic example of suspension is the sand mixed with water as was shown in our activity. As you can see, the sand is not dissolved in water; it is merely suspended in it. The suspension produced is not also clear; it is actually opaque. And upon standing, you can see that the sand is slowly settling. In this regard, the composition of suspension is actually changing as the sand settles in, so it is a *heterogenous* mixture, unlike that of the solution. Also, when the clay particles are allowed to pass through the improvised filter paper, the sand is left behind. This is because the particles of a suspension are too large to pass through the filter paper, or through a membrane with finer openings.

Energy in the Dissolution Process

Get a glass of water and put a pinch of powder dye. Observe the pattern of the movement of dye in water. What you just did best describes the dissolution process which fascinates chemists for years. The dissolution process is due to intermolecular forces (forces that exist between molecules). When two molecules overcome the attractive forces that exist between them, they absorb energy. On the other hand, when the attractive force is formed between two molecules, they release energy. Thus, we can say that dissolution process involves the absorption (*endothermic*) and release (*exothermic*) of energy. When the energy absorbed is greater than the energy released, the dissolution process is endothermic. The opposite scenario is true for exothermic process.

Think?

The process of removing stain in shirts involves a process of dissolving stain in water. It is an exothermic process because energy absorbed between stain and water is less than the energy released when blood is hydrated. How can you easily remove the stain using water alone?

Solubility is the measure of how much solute will dissolve in a solvent at a specific temperature. The famous saying “like dissolves like” is important in predicting the solubility of a substance in a given solvent. This expression means that when two substances of same intermolecular forces and magnitude are mixed, they are likely to be soluble to one another. Take for example salt (NaCl) and water (H_2O) which are both polar. When these two substances are mixed, the attraction between NaCl and H_2O molecules has the same magnitude to the forces between NaCl molecules and between H_2O molecules. However, solubility is often confused with miscibility. ***Miscibility*** is the term used when two liquids are completely soluble with one another in all proportions while *solubility* is the term used when a *solid or gas* is completely soluble in liquid in all proportions. For example, alcohol and water are miscible to one another.

What you will do

Self-Test 1.1

Now that you are through with the first lesson, try to answer the following and see for yourself how much you learned.

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. What do you call a mixture that is not evenly distributed in all proportions and cannot be separated by filtration?
   a. colloid
   b. solution
   c. suspension
   d. homogenous mixture

2. All of the following will exhibit a homogenous mixture **EXCEPT**
   a. salt and water
   b. sand and water
   c. sugar and water
   d. alcohol and water

3. When oil is mixed with water, the mixture is said to be __________ to one another.
   a. soluble
   b. miscible
   c. insoluble
   d. immiscible

4. What is the dissolving substance in a solution?
   a. water
   b. solute
   c. solvent
   d. particles

5. Substance A was dissolved in water, and the energy absorbed in overcoming the attractive intermolecular forces between the molecules is 500 kJ. The energy released when substance A was dissolved in water is 800 kJ. How will you describe the dissolution process?
   a. basic
   b. acidic
   c. endothermic
   d. exothermic

Key to answers on page 25.

Lesson 2. What Makes a Solute Dissolve Faster?

The ***solubility*** of a substance is the maximum amount of solute that can be dissolved in a certain amount of solvent at a certain temperature. In this case, water is assumed as the solvent unless otherwise stated. But, there are also other solvents that can be used. One common solvent is alcohol. An alcohol solution used medicinally is called "*tincture*". Thus, a tincture of iodine contains iodine dissolved in alcohol.

There are actually different factors that contribute to the rate of dissolution of solute in the solution. To clearly understand these factors, do Activity 2.1.

What you will do

Activity 2.1 How can we make solutes dissolve faster?

Materials:
- Sugar
- Glass of hot water
- Glass of cold water
- Oil
- Mortar and pestle
- Boiling water in a kettle

Procedure:

1. Place a spoonful of sugar in a glass of hot water and in a glass of cold water. Where did sugar dissolve faster? Why?

2. Repeat step 1. But this time, stir the sugar simultaneously in both glasses until it completely dissolves. In which of the two set-ups did sugar dissolve faster?

3. Using a mortar and pestle, pound the sugar simultaneously until it is completely

pulverized. Then, add the powdered sugar to the glass of hot water and cold water and stir. Compare the result with Step 1.

4. Mix oil in a glass of hot water and in a glass of cold water. Take note of the result. Did the oil dissolve in water?

5. Heat water in the kettle until it boils. Observe the bubbles formed on the side of the kettle even before the water boils. What happens to the bubbles as the water “boils out”?

Analysis:

1. What happens when sugar is stirred?
2. What happens to the rate of solubility of sugar when heat is applied?
3. What is the effect of particle size on the rate of dissolving?
4. What can you infer about the solubility of gases (water vapor) as the temperature increases as in step 5?

Factors Affecting Solubility of a Solute

A. Temperature

In the previous experiment, you were able to dissolve excess solute upon heating. Thus, temperature affects the solubility of substances. The solubility of a solid in liquid usually increases with increasing temperature since most dissolution process that involves a solid solute over a liquid solvent is endothermic. However, in the case of the solubility of gas in liquid, increasing the temperature will usually result to decrease in solubility.

Did you know?

Are you a softdrinks addict? The reason why we love to drink carbonated drinks is because of the biting taste caused by carbon dioxide gas dissolved in the solution. Cleopatra craved for it, too. She used pearls in her beverage. These pearls contained calcium carbonate which could react with water to produce carbon dioxide. But you know how expensive pearls are nowadays. Today, carbon dioxide is dissolved in liquid by decreasing the temperature and increasing the pressure. This is how commercially available carbonated drinks are made.

B. Nature of Solvent

The ability of a solute to be dissolved in a given solvent is affected by the type of bond of both the solute and solvent. In general, polar liquids dissolve polar compounds and the same is true with nonpolar liquids. Thus goes the saying "*like dissolves like*". This is the guiding rule in preparing solutions. Since water is a polar liquid, it dissolves polar compounds such as sugar ($C_6H_{12}O_6$) and salt (NaCl). Sometimes, in spite of all attempts, a substance does not appreciably dissolve in water even though it is polar. These substances are called *insoluble salts* (Table 2.1)

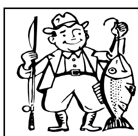
Table 2.1 Water Solubililty of Common Salts and Bases

Soluble	Insoluble
Sodium salts Potassium salts Ammonium salts Acetates Nitrates Chlorides (except silver, lead, and mercury) Sulfates (except calcium, barium and lead)	Carbonates (except sodium, potassium and ammonium) Phosphates (except sodium, potassium and ammonium) Sulfides (except sodium, potassium and ammonium) Hydroxides (except sodium, potassium and ammonium)

C. Pressure

The effect of pressure on the solubility of a solid or liquid solute is not as noticeable as that of a gaseous solute. *The solubility of gases in water usually increases with increasing pressure.* This relationship is first noticed by William Henry (1775-1836) in 1803 and its law is called after his name—***Henry's law or Pressure-Solubility Law***. This law states that in a given temperature, the mass of a gas that dissolves in a given volume of liquid is directly related to its pressure.

An example is the carbon dioxide gas dissolved in carbonated drinks. If the bottle is closed, the carbon dioxide gas remains dissolved in the beverage due to considerable amount of partial pressure present. But if it is opened, the pressure is released and carbon dioxide gas bubbles off the liquid due to a decrease in gas solubility.



Did you know?

On a hot summer day, an experienced fisherman would usually pick a deep spot in the river or lake to cast the bait because the oxygen content is greater in the deeper, cooler region. Alas! most fish will be found there. So next time you try fishing on a summer day, try this secret technique for a more enjoyable recreation.

Factors Affecting the Rate of Dissolution

A. Surface area

Surface area does not affect the amount of solute that will dissolve, but it does affect the solute's rate of dissolution. Thus, in order to make a solid solute dissolve faster, we frequently powder it, thereby increasing the surface area. This is why powdered coffee dissolves faster than granulated coffee even without stirring.

B. Rate of Stirring

The rate at which a solute dissolves can be increased by *stirring* the mixture. This process brings fresh solvent into contact with the solute and so permits a faster rate of dissolution.

C. Temperature

Generally, solubility increases with increasing temperature for most cases of solid in liquid. The increase in temperature causes an increase in kinetic energy of the solute, solvent and the solution thus facilitating rapid interaction with one another.

Saturated, Unsaturated and Supersaturated Solutions

Solutions can also be classified as saturated, unsaturated and supersaturated. When a small amount of sugar is mixed in a glass of water, all the sugar will dissolve. If more and more sugar is added while stirring, a point is reached when some sugar will settle at the bottom of the glass even with continued rapid stirring. This type of solution is said to be saturated. Thus, a *saturated solution* is one that contains as much of the solute as it can hold at a given temperature. An *unsaturated solution* contains less solute than it has the capacity to dissolve.

The third type, the *supersaturated solution* contains more solute than is present in a saturated solution. This is a rather unstable condition. In this case, the excess solid will eventually separate from the solution as a precipitate in a process known as *precipitation* or as crystals in a process known as *crystallization*. Crystals have bigger granules than precipitate. Tawas or alum crystals are prepared as supersaturated solutions.

What you will do

Self-Test 2.1

Again, try to check how much you have learned from the lesson by answering the following questions.

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Which of the following affects both the rate of solution and the solubility of a solid in a liquid?
    a. stirring
    b. increasing pressure
    c. increasing surface area exposed
    d. increased in temperature

2. Which solution contains more dissolved solute than a saturated solution contains under the same conditions?
    a. saturated
    b. unsaturated
    c. concentrated
    d. supersaturated

3. All of the following are soluble in water **EXCEPT**
    a. lead acetate
    b. lead sulfate
    c. lead chloride
    d. lead phosphate

4. Which substance usually becomes less soluble with increasing temperature?
    a. gas
    b. solid
    c. liquid
    d. all of the above

5. All of the following affect the solubility of solid in liquid **EXCEPT**
    a. pressure
    b. temperature
    c. surface area
    d. nature of solvent

Did you encounter any problem? Well, compare your answers with the answer key and see for yourself the items you missed. Good luck!

Key to answers on page 25.

Lesson 3. How Much Solute Can Be Dissolved in a Solution?

In order to clearly understand solutions, we must know how much of the solute is present in the solution and also how to control the amounts of solute used to bring about a saturated, unsaturated or supersaturated solution.

The ***concentration of a solution*** is the amount of solute present in a given quantity of solvent or solution. For simplicity of the discussion, we will assume the solute is a liquid or solid and the solvent is a liquid. Chemists use several different concentration units, each of which has advantages as well as limitations. Let us examine four most common units of concentration: *percent composition, mole fraction, molarity, and molality.*

Types of concentration units

A. Percent composition

The percent of the solute in the solution is referred to as **percent composition**. In expressing the percent concentration, the units mass or volume are used. The following are the different ways of expressing percent composition.

1. Percent by mass (% m/m)

The percent by mass (also called percent by weight or weight percent) is the ratio of the mass of solute to the mass of solution, multiplied by 100 percent:

$$\textit{Percent by mass of solute} = \frac{\textit{mass of solute}}{\textit{mass of solution}} \times \textit{100\%}$$

Sometimes, percent by mass is also termed as mass fraction only that the percentage multiplier is deleted. Mass fraction is just the fraction of the mass of the solute over the total mass of the solution. Mass fractions of very dilute solutions are often expressed in parts per million (abbreviated as ppm). One part per million is equivalent to one gram of solute per one million grams of solution, or one milligram of solute per thousand grams of solution (1mg/kg). For even smaller mass fractions, parts per billion (ppb) and parts per trillion (ppt) are often used. And as their name implies, we can express the mass fraction as parts per million by multiplying it by 1 000 000 ppm (106ppm) or 1 000 000 000 ppb (109 ppb) and so on.

Sample Problem:

A healthy snack claims to contain "low sodium" (Na^+). It contains 30 mg of Na^+ (molecular weight is 23 g/mol) in each 8-oz serving (8 oz = 250 mL). What is the concentration of sodium in terms of ppm? (1ppm = 1mg/L).

Explanation:

$$\frac{30\text{ mg of Na}^+}{250\text{ mL}} \times \frac{1000\text{ mL}}{1\text{ L}} = 120\text{ mg/L}$$

Since 1 ppm is equivalent to 1 mg/L, then sodium content is also 120 ppm.

2. Percent by volume (% v/v)

On the other hand, the percent by volume is expressed the same as percent by mass only that mass is changed to volume, as given by the equation:

$$\text{Percent by volume of solute} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$

Sample Problem:

If you are asked to prepare 500 mL of pineapple-orange juice whose concentration is 60% (v/v) orange juice and 40% (v/v) pineapple juice, how are you going to mix it with the right combination?

Explanation:

Remember that 60% (v/v) orange juice is the same as 60 mL of orange juice in 100 mL solution. The same goes for 40% (v/v) pineapple juice which is 40 mL of pineapple juice in 100 mL solution. So, in a 500 mL pineapple-orange juice, the volume would be:

$$\frac{60\ \text{mL orange juice}}{100\ \text{mL juice solution}} \times 500\ \text{mL} = 300\ \text{mL of orange juice}$$

$$\frac{40\ \text{mL pineapple juice}}{100\ \text{mL juice solution}} \times 500\text{mL} = 200\ \text{mL of pineapple juice}$$

Therefore, in order to get the right combination, you just have to mix 300 mL of orange juice to 200 mL pineapple juice to make a pineapple-orange juice, the total volume of which is 500 mL.

3. *Percent mass by volume (% m/v)*

The same is true for percent by weight-volume. It is expressed the same as percent by mass but the denominator is changed to volume instead, as given by the equation:

$$\text{Percent by weight - volume of solute} = \frac{\text{mass of solute}}{\text{volume of solution}} \times 100\%$$

Sample Problem:

You are asked to add 30 mg salt (NaCl) in 20 mL solution to a favorite adobo dish. This concentration is just enough to give your adobo a salty taste. Express this in percent concentration. (Note: 1 mg = 0.001 g)

Explanation:

$$\frac{0.03\ \text{g NaCl}}{20\ \text{mL solution}} \times 100 = 0.15\%\ \text{NaCl solution}$$

What you will do

Practice Exercise 3.1

1. An alcoholic drink claims 12% alcohol by volume. Calculate the volume in mL of alcohol present in a 0.8 L wine.
2. How much sugar ($C_{12}H_{22}O_{11}$) in grams must be added to 450 mL water to make a 20% sugar solution?
3. How much bagoong (fish paste) in grams will you add to 1.5 kg mixed vegetables to be able to come up with a delicious pinakbet with percent by mass concentration of 30%? (1 kg = 1000 g)

Key to answers on page 26.

B. Mole fraction

Another method of expressing concentration is by ratio solution. A 1:10 salt solution is 1 g of salt in 10 mL solution. The first number in the ratio indicates the number of grams of solute and the second number gives the number of milliliters of solution. One way of expressing ratio solutions is by *Mole fraction*. It is the ratio of the individual component of the solution to the total component of the solution.

$$\text{Mole fraction of component } A\ (X_A) = \frac{\text{moles of } A}{\text{sum of moles of all components}}$$

Since it is a ratio of two similar quantities, the mole fraction has no units.

Sample Problem:

Calculate the mole fraction of solute and solvent in a 15% aqueous sugar solution ($C_{12}H_{22}O_{11}$). Note: An aqueous solution is a solution where water is the solvent.

Explanation:

Always assume the mass of the solution as 100 g. Therefore, in a 15% aqueous sugar solution ($C_{12}H_{22}O_{11}$), there are 15 g of sugar (solute) to be dissolved in 85 g water (solvent). And the number of moles is computed as:

$$15\text{ g } C_{12}H_{22}O_{11} \times \frac{1\text{ mol } C_{12}H_{22}O_{11}}{342\text{ g } C_{12}H_{22}O_{11}} = 0.044\text{ mol } C_{12}H_{22}O_{11}$$

$$85\text{ g } H_2O \times \frac{1\text{ mol } C_{12}H_{22}O_{11}}{18\text{ g } H_2O} = 4.72\text{ mol } H_2O$$

Then, the mole fraction of solute and solvent in the solution is computed as:

$$\text{Mole fraction of } C_{12}H_{22}O_{11} = \frac{0.044}{0.044 + 4.72} = 0.01$$

$$\text{Mole fraction of } H_2O = \frac{4.72}{0.044 + 4.72} = 0.99$$

What you will do

Practice Exercise 3.2

Calculate the mole fraction of solute and solvent in a 30% aqueous sugar solution ($C_{12}H_{22}O_{11}$). Note: An aqueous solution is a solution where water is the solvent.

Key to answers on page 26.

C. Molarity (M)

Molar solutions are used most frequently by chemists. A molar solution is defined as one that contains 1 mole of solute per liter of solution.

$$\textit{Molarity} = \frac{\textit{moles of solute}}{\textit{liters of solution}}$$

Sample Problem:

For you to better understand molarity, let us use the same problem in ratio solutions but let us change the concentration.

You need to prepare 1 L (1 L = 1000 mL) of “arnibal” (it is a brown sugar solution) for your sago-gulaman juice, the concentration of which is 2 M. How much sugar will you need to add to water?

Explanation:

The problem calls for the preparation of 1 L of 2 M sugar solution, $C_6H_{12}O_6$ (molecular weight is 180 g/mol). Recall that molarity means moles per liter. So,

$$1\ L \times 2\ M\ C_6H_{12}O_6 = 2\ \text{moles}\ C_6H_{12}O_6$$

Then, since 1 mol weighs 180 g,

$$2\ \text{moles}\ C_6H_{12}O_6 \times \frac{180\ g\ C_6H_{12}O_6}{1\ \text{mole}\ C_6H_{12}O_6} = 360\ g\ C_6H_{12}O_6$$

Therefore, we take 360 g $C_6H_{12}O_6$, dissolve it in water, and dilute to a total of 1 L.

What you will do

Practice Exercise 3.3

A juice advertised as "low sodium" contains 12 mg Na^+ (molecular weight is 23 g/mol) in each 8-oz serving (8 oz = 250 mL). What is the concentration of sodium in the beverage in terms of molarity?

Key to answers on page 26.

D. Molality (m)

Molality is the number of moles of solute dissolved in 1 kg (1000 g) of solvent: that is,

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

Sample Problem:

How will you express 30% aqueous sugar solution ($C_{12}H_{22}O_{11}$) in molal concentration?

Explanation:

Always assume the mass of the solution as 100 g. Therefore, in a 30% aqueous sugar solution ($C_{12}H_{22}O_{11}$), there are 30 g of sugar (solute) to be dissolved in 70 g water (solvent). So:

$$\frac{30\text{ g } C_{12}H_{22}O_{11}}{70\text{ g } H_2O} \times \frac{1\text{ mol } C_{12}H_{22}O_{11}}{342\text{ g } C_{12}H_{22}O_{11}} \times \frac{1000\text{ g } H_2O}{1\text{ kg } H_2O} = 1.25\text{ m } C_{12}H_{22}O_{11}$$

Molarity is most often used over molality because it is generally easier to measure the volume of the solution using precisely calibrated volumetric flask than to weigh the solvent. However, when accuracy of the experiment is at stake, molality is preferred over molarity because the volume of the solution typically increases with increasing temperature. For example, a solution at 1.0 M at 25°C may become 0.95 M at 45°C because of the increase in volume.

What you will do

Practice Exercise 3.4

How will you express 60% aqueous sugar solution ($C_{12}H_{22}O_{11}$) in terms of molality?

Key to answers on page 26.

Dilution Solutions

Sometimes, it is often necessary to prepare a weaker (dilute) solution from a stronger (concentrated) solution. To do so, we must add water to the stronger solution. But how much water must be added? To answer this question, we use the relationship:

Initial concentration x Initial volume = Final concentration x Final volume

$$C_1V_1 = C_2V_2$$

where the initial concentration and initial volume are the strength and amount of concentrated solution to be used; and the final concentration and final volume are the strength and amount of diluted solution to be used.

Sample Problem:

At dinner, the visitors found the orange juice prepared by your brother too sweet. Your brother said he just mixed 70 g of powdered orange juice in 500 mL of water. When you read the label, the suggested preparation was 60 g of powdered juice for 500 mL of water. The best thing to do is to dilute the orange juice prepared by adding water.

How much water will you add?

Explanation:

Using the above formula for diluting solutions, the amount of water to be added can be computed as:

$$60\text{ g} \times (x\text{ mL of 60 g powdered orange}) = 70\text{ g} \times 500\text{ mL}$$

$$x = \frac{70\text{ g} \times 500\text{ mL}}{60\text{g}}$$

$$x = 583\text{ mL}$$

Therefore, in order to have the right orangy taste as prescribed by the manufacturer, you must add 83 mL of water (583 – 500 = 83) to your brother's prepared juice.

What you will do
Practice Exercise 3.5

Let us make a scenario.

You were unable to copy your mom's specialty "hinilabos na talangka" (salted crablets) and your guests found it too salty. You prepared it by adding 10% salt (NaCl) solution to your crablets before steaming. How much water are you going to add if your mom said that she prepared her specialty by mixing 20 mL of 0.5% salt (NaCl) solution instead?

Key to answers on page 26.

What you will do
Self-Test 3.1

Let us try to check how much you have learned from this lesson by answering the following questions.

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Which of the following is the **most** concentrated solution?
    a. 2 M NaCl solution
    b. 3 m NaCl solution
    c. 2 M Na2SO4
    d. 2 g of NaCl in 100 mL solution

2. A solution labeled "5% NaCl" is assumed to contain 5 g NaCl per __________.
    a. 100 mL water
    b. 100 mL solvent
    c. 100 mL solution
    d. none of the above

3. How much salt is present in a 5 M salt solution (Molecular weight = 58 g/mol)?
    a. 0.09 g
    b. 11.6 g
    c. 290 g
    d. none of the above

4. A juice claims to contain 180 mg of Na^+ (molecular weight is 23 g/mol) in each 8-oz serving (8 oz = 250 mL). What is the concentration of sodium in terms of ppm?
    a. 0.72 ppm
    b. 7.2 ppm
    c. 72 ppm
    d. 720 ppm

5. The active ingredient in one brand of antacid is magnesium oxide, MgO (Molecular Weight = 40.31 g / mol). If it is dissolved in 250 mL water at a ratio of 1:10, how many grams of MgO must be dissolved in the solution?
    a. 25 g
    b. 250 g
    c. 2500 g
    d. none of the above

Key to answers on page 26.

Lesson 4. Why Do You Need to Study Solutions?

Water is usually referred to as the *universal solvent*. The electrical charges in water molecules help dissolve different kinds of substances. Solutions form when the force of attraction between the solute and the solvent is greater than the force of attraction between the particles in the solute. This type of solutions where water is the solvent is called ***aqueous solutions***. One example of an important process is chemical weathering. *Chemical weathering* begins to take place when carbon dioxide in the air dissolves in rainwater. A solution called carbonic acid is formed. The process is then completed as the acidic water seeps into rocks and dissolves underground limestone deposits. Sometimes, the dissolving of soluble minerals in rocks can even lead to the formation of caves.

If one takes a moment to consider aqueous solutions, one quickly observes that they exhibit many interesting properties. For example, the tap water in your kitchen sink does not freeze at exactly 0ºC. This is because tap water is not pure water; it contains dissolved solutes. Some tap water, commonly known as *hard water*, contains mineral solutes such as calcium carbonate, magnesium sulfate, calcium chloride, and iron sulfate.

Did you know?

The amount of oxygen required to oxidize a given quantity of organic material is known as the ***biochemical oxygen demand (BOD)***. This is one indicator of water pollution. Interestingly, some microorganisms, the anaerobic bacteria, can "eat" certain highly toxic substances and convert it to less toxic ones.

The reduced solubility of oxygen in hot water has a direct bearing on thermal pollution—that is, the heating of the environment (usually waterways) to temperatures that are harmful to its living inhabitants. Fish, like all other cold-blooded animals, have much more difficulty coping with rapid temperature fluctuation in the environment than we humans do. The increase in water temperature accelerates their rate of metabolism, which generally doubles with each $10^{o}C$ rise. The results can be drastic because the rate of oxygen demand for fishes does not support the oxygen supply available because of its lower solubility in heated water. Thus, effective ways of cooling power plants with minimal damage to biological environment are being sought.

Environmental Awareness

We often don't think about what we throw away, or how our household wastes can affect groundwater, lakes, rivers, and coastlines. Thus, we should be more vigilant to participate in recycling programs. A substance is ***biodegradable*** if it can be broken down by microorganisms. Some organic compounds are ***non-biodegradable***, presumably because their structures are such that microorganisms cannot use them for food, or because they are toxic and can kill the microorganisms.

Have you heard of the term pH? I am sure you have heard of the term pH-balanced in a TV commercial. Have you ever wondered what it means?

pH indicates whether a solution is acidic or basic. If the pH is less than 7, the solution is considered acidic. If the pH is greater than 7, the solution is basic. At pH 7, the solution is said to be neutral.

Solutions in the body have to maintain a specific pH range. For example, in order to have a healthy hair, the pH must be maintained at pH between 4 and 7. This means that our hair is slightly acidic, and for it to remain healthy, it must be exposed to shampoo or conditioners of same pH range.

Table 4.1 pH of Body Fluids

Body Fluids	pH
Plasma	7.4
Interstitial fluid	7.4
Cerebrospinal fluid	7.3
Saliva	5.8-7.1
Urine	4.6-8.0
Sweat / perspiration	4.0-6.8
Gastric juice	1.6-1.8

Could you justify the pH of the body fluids listed in table 4.1? What should you do to maintain a healthy pH range of each body fluids?

What you will do

Self-Test 4.1

Let us try to check how much you have learned from the lesson by answering the following questions.

Fill in the blanks with the correct answer.

________________1. A substance that can be broken down by microorganisms

________________2. It begins to take place when carbon dioxide in the air dissolves in rainwater forming carbonic acid.

________________3. A microorganism which determines the biochemical oxygen demand (BOD) number in water pollution

________________4. It refers to the heating of the environment (usually waterways) to temperatures that are harmful to its living inhabitants.

________________5. It is the term used when tap water contains mineral solutes such as calcium carbonate, magnesium sulfate, calcium chloride, and iron sulfate.

Did you encounter any problem? Well, compare your answers with the answer key and see for yourself the items you missed. Good luck!

Key to answers on page 26.

Let's Summarize

A. Summary of Key Equations

$$\text{Percent by mass of solute (\%m/m)} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100\%$$

$$\text{Percent by volume of solute (\%v/v)} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100\%$$

$$\text{Percent by weight - volume of solute (\%m/v)} = \frac{\text{mass of solute}}{\text{volume of solution}} \times 100\%$$

$$\text{Mole fraction of component A } (X_A) = \frac{\text{moles of A}}{\text{sum of moles of all components}}$$

$$\text{Molarity (M)} = \frac{\text{moles of solute}}{\text{liters of solution}}$$

$$\text{Molality (m)} = \frac{\text{moles of solute}}{\text{mass of solvent (kg)}}$$

Dilution Solutions: $C_1V_1 = C_2V_2$

B. Summary of Facts and Concepts

1. Solutions are homogenous mixtures of two or more substances, which may either be solids, liquids or gases. They are clear, have a variable composition, do not settle, can be separated by physical means and can be separated by filtration.
2. Solutions can also be classified as diluted or concentrated according to relative amount of components present.
3. Suspension is defined as fine particles of solid in a liquid and because it is transparent, it does not settle out and cannot be separated by filtration.
4. Solutions are composed of *solutes*, the substance dissolved and the *solvent*, the liquid material in which the solute has dissolved.
5. The dissolving process involves physical changes (phase changes) and both absorption and evolution of energy. If more energy was absorbed than evolved, the process is endothermic. If more energy was evolved than absorbed, the dissolution process is exothermic.
6. Solubility is the maximum amount of solute that will dissolve in a solvent at a specific temperature. The solubility of a solute is affected by temperature, pressure, and nature of the solvent. The rate of dissolution is affected by surface area, rate of stirring and temperature.

7. Increasing temperature usually increases the solubility of solid and liquid substances, and decreases the solubility of gases in water.
8. The greater the pressure, the greater the solubility of a gas in liquid.
9. A saturated solution is when there is no more solute that will dissolve in the solvent. An unsaturated solution contains less solute than it has the capacity to dissolve. A supersaturated solution contains more solute than is present in a saturated solution.
10. The concentration of a solution may be expressed in terms of percentage (by weight, by volume, or by weight-volume), ratio (mole fraction), molarity and molality. The choice of units depends on the purpose of the measurement.
11. Numerical values of pH indicate whether a solution is acidic or basic.

Posttest

I. Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. A solution has all the following properties **EXCEPT**
   a. clear
   b. homogenous
   c. cannot pass through filter paper
   d. can be separated by physical means

2. A solution that contains the maximum amount of dissolved solute is:
   a. saturated
   b. unsaturated
   c. concentrated
   d. supersaturated

3. When there is less solute in relation to the solvent, the solution is said to be:
   a. dilute
   b. unsaturated
   c. supersaturated
   d. none of the above

4. Water in a creek near a busy highway was analyzed for salt content and found to contain 0.0276 g NaCl per 100 mL solution. What is the concentration of the NaCl expressed in ppm?
   a. 0.276
   b. 2.76
   c. 27.6
   d. 276

5. All of the following affects the solubility of a solid in a liquid **EXCEPT**
   a. stirring
   b. pressure
   c. surface area
   d. temperature

6. When alcohol is mixed with water, the mixture is said to be __________ to one another.
   a. soluble
   b. miscible
   c. insoluble
   d. immiscible

7. Liquids that **DO NOT** dissolve freely in one another in any proportion are known as:
    a. solutions
    b. emulsions
    c. homogenous mixtures
    d. heterogenous mixtures

8. All of the following are biodegradable substances **EXCEPT**
    a. glass
    b. tissue paper
    c. animal feces
    d. fruit peelings

9. A "10% NaCl solution" contains 10 g NaCl per __________.
    a. 100 mL water
    b. 100 mL solvent
    c. 100 mL solution
    d. 1000 mL solution

10. What kind of solution contains less solute than it has the capacity to dissolve?
    a. diluted
    b. saturated
    c. unsaturated
    d. supersaturated

11. Which factor will increase the amount of dissolved oxygen in a body of water?
    a. onset of cooler season
    b. presence of more fishes
    c. contamination of body of water
    d. increased volume of oxygen in the atmosphere

12. The dissolution of sodium hydroxide pellets in water is an exothermic process. Which can be done to increase the solubility of the sodium hydroxide pellets in 100 mL of water?
    a. increase pressure of the solution
    b. decrease the pressure of the solution
    c. increase temperature of the solution
    d. decrease temperature of the solution

13. Sterling silver contains 95% silver. If a necklace made of sterling silver weighs 15 g, what is the mass of silver dissolved in the necklace?
    a. 1.6 g
    b. 6.2 g
    c. 9.0 g
    d. 14.25 g

14. The pH of gastric juice is 1.6-1.8. Which of the following is the reason for its acidic nature?
    a. It kills most of the bacteria taken in along with food.
    b. It triggers secretion of acidic fluid containing bicarbonate ions.
    c. It facilitates build up of proteins from an inactive to active form.
    d. It inhibits the secretion of pancreas of an alkaline fluid containing bicarbonate ions.

15. Which of the following triggers Thermal Pollution?
    a. increase in fishes
    b. increase in temperature
    c. increase in carbon dioxide supply
    d. all of the above

II. True or False. Write the word **TRUE** if the statement is correct and **FALSE** if it is incorrect.

_________ 1. Solutions are heterogenous mixtures.
_________ 2. Solubility of a solid in liquid increases with increasing temperature.
_________ 3. Water can dissolve anything that is why it is called the universal solvent.
_________ 4. Solubility of a gas in liquid increase with increasing pressure.
_________ 5. Solutions expressed in molarity and molarity are the same when water is the solvent.

Key to answers on page 27.

Key to Answers

Pretest

I. Multiple Choice

1. a
2. a
3. a
4. d
5. c
6. a
7. a
8. c
9. a
10. b

II. True or False

1. True
2. True
3. False
4. False
5. False

Lesson 1

Self-Test 1.1

1. c
2. b
3. d
4. c
5. d

Lesson 2

Self-Test 2.1

1. d
2. d
3. d
4. a
5. a

Lesson 3

Practice Exercise 3.1

1. 96 mL alcohol
2. 31 g sugar
3. 300 g bagoong

Practice Exercise 3.2

Mole fraction of $C_{12}H_{22}O_{11}$ is 0.02 and water is 0.98.

Practice Exercise 3.3

0.002 M Na^{+}

Practice Exercise 3.4

4.39 m

Practice Exercise 3.5

19 mL water

Self-Test 3.1

1. b
2. c
3. a
4. d
5. a

Lesson 4

Self-Test 4.1

1. Biodegradable
2. Chemical weathering
3. Anaerobic Bacteria
4. Thermal pollution
5. Hard water

Posttest

I. Multiple Choice			II. True or False
1. c	6. b	11. a	1. False
2. a	7. d	12. c	2. False
3. a	8. a	13. d	3. False
4. d	9. c	14. a	4. True
5. b	10. c	15. b	5. True

References

Araneta, F.L. & Catris, L.V. (2002). *The world of chemistry: Exploring the natural world series).* Manila: SIBS Publishing House Inc.

Chang, R.N. (2004). *Chemistry.* (8th ed.) USA: McGraw-Hill, Inc.

Green, J. & Damji, S. (2001). *Chemistry*. (2nd ed.) Australia: IBID Press, Victoria.

Magno, M.C., Tan, M.C. & Punzalan, A.G. (2000). *Chemistry.* (3rd ed.) Manila: DIWA Learning Systems, Inc.

Moore, J.W., Stanitski, C.L. & Wood J.L. (1998). *The chemical world: Concepts and applications*. (2nd ed.) USA: Harcourt Brace & Company.

Petrucci, R.H. & Harwood, W.S. (1998). *General chemistry: Principles and modern applications.* (7th ed.) New Jersey: Prentice-Hall International.

Regalado, E.C. (2000). *Chemistry*. Philippines: St. Augustine Publications, Inc.

Sackheim, G.I. & Lehman, D.D. (1990). *Chemistry for the health sciences.* (6th ed.) New York: Macmillan Publishing Company.