SOLUTIONS AND COLLOIDS

OBJECTIVES

1. To examine the influence of solvent and solute on solution formation
2. To prepare a solution for use in a later experiment
3. To make a colloid and demonstrate its properties

INTRODUCTION

Part I. Influence of solute and solvent on solubility

Solutions are homogeneous mixtures of two or more chemical substances. The components can be gases, liquids, or solids, and they are uniformly distributed. As a result, the properties of a true solution are the same throughout the solution. The component of a solution that produces dissolution is called the solvent and is often present in greater proportion. The component that is dissolved is called the solute. The components of the solution are of atomic or molecular size. Thus they are too small to reflect light and solutions will be transparent, though they may be colored or colorless. Often, then, it becomes necessary to use chemical and physical tests to identify a substance as a solution rather than as pure solvent. Chemical tests, such as the formation of a precipitate (studied in the experiment on chemical reactions), are frequently used to identify ions or molecules in a solution.

The solubility of a solute in a particular solvent is a property of that solute. Commonly, the solubility of a solute in a liquid is reported in grams of solute per 100 mL of solvent. Several factors may influence the solubility of a solute, including temperature, the nature of the solute, and the nature of the solvent. To understand how the nature of the solute and solvent affect solubility, the concept of intermolecular forces must be examined. These are the forces of attraction among particles, and they exist among solute particles and among solvent particles. In order for a solute particle to dissolve, its interactions with other solute particles must be overcome and new interactions with the solvent must form. This happens most readily when intermolecular forces between solute and solvent are similar. If the interactions between solute particles are stronger than those between solute and solvent, the solute will not dissolve. Thus polar covalent and soluble ionic compounds are soluble in polar solvents such as water, and insoluble in nonpolar solvents such as benzene and carbon tetrachloride. Nonpolar covalent compounds, on the other hand, are much more soluble in nonpolar solvents than in polar solvents. Thus the general rule-of-thumb is "like dissolves like".

Soluble substances dissolve completely in the solvent and form solutions. Insoluble substances do not dissolve in the solvent. Two liquids that are completely soluble in each other are called miscible. When a liquid solute doesn't dissolve in a liquid solvent, but instead forms a separate layer, the liquids are said to be immiscible.

In Part I of this experiment, you will test the solubility of a series of compounds in two solvents, one polar and one nonpolar.

Part II. Preparation of a solution

Since many of the reactions carried out in laboratories and all of those in our bodies take place in solution, it is necessary to be able to determine the concentration of the solute, or the relationship between the quantities of solute and solvent found in solutions. Concentrations can be given in many units, but one of the most commonly used in chemistry is molarity. Concentration expressed as molarity gives the relationship between the number of moles of solute and the volume of solution. It is defined as:

$$\text{molarity} = M = \frac{\text{moles of solute}}{\text{liter of solution}} \qquad (1)$$

In order to make a solution of a given molarity, you can weigh out a calculated amount of solute and dissolve it in enough solvent to make the desired volume of solution. For example, to make 100.0 mL of a 0.100 M NaCl solution, you need:

$$100.0 \text{ mL solution} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times \frac{0.100 \text{ mol NaCl}}{\text{L solution}} = 0.0100 \text{ moles NaCl} \qquad (2)$$

This requires you to weigh out:

$$0.0100 \text{ moles NaCl} \times 58.5 \text{ g/mol NaCl} = 0.585 \text{ g NaCl} \qquad (3)$$

To prepare the solution, you would weigh out 0.585 g of NaCl, add enough water to dissolve, then dilute to a total volume of 100.0 mL using a 100 mL volumetric flask.

To calculate the concentration of a solution prepared from a known mass of solute, you must find the number of moles of that solute, then divide by the total volume of solution. For example, if you weigh out 0.784 g of NaCl and dissolve it in a total volume of 150.0 mL:

$$0.784 \text{ g NaCl} \times \frac{1 \text{ mole}}{58.5 \text{ g}} = 0.0134 \text{ moles NaCl} \qquad (4)$$

$$\frac{0.0134 \text{ moles NaCl}}{150.0 \text{ mL}} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.0893 \text{ mol/L NaCl} = 0.0893 \text{ M} \qquad (5)$$

In Part II, you will prepare a solution and determine its concentration for use in a subsequent experiment.

Part III. Colloids

Part III of this experiment examines colloids. Colloidal suspensions consist of a dispersing medium and a dispersed material. These can be solids, liquids, or gases. The dispersed material exists as particles that are much larger than those in a true solution. Though they are small enough to remain suspended in the dispersing medium, they are large enough to scatter light when an intense beam of light passes through the suspension. This property of colloids is called the Tyndall effect. Some examples of colloids include milk (a liquid dispersed in a liquid), smoke (solids in a gas), whipped cream (a gas in a liquid), and fog (a liquid in air).

In Part III, you will compare a solution and a colloid, using the Tyndall effect to test for the presence of the colloid.

PROCEDURE

Part I. Influence of solute and solvent on solubility

A. Place 8-10 drops of water in each of 9 test tubes. Then add the following solutes and test for solubility. For solids, add a few crystals. For liquids, add 8-10 drops. Shake to mix and record your observations.

a. methanol (CH_3OH)
b. ethanol (CH_3CH_2OH)
c. n-propanol ($CH_3CH_2CH_2OH$)
d. n-butanol ($CH_3CH_2CH_2CH_2OH$)
e. NaCl
f. table sugar ($C_{12}H_{22}O_{11}$)
g. oil (mixture of compounds containing mostly carbons and hydrogens)
h. $MgSO_4$
i. n-octanol ($CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_2OH$)

B. Repeat the experiment, using 8-10 drops of oil in each test tube instead of water.

Part II. Preparation of a solution

CAUTION: SODIUM HYDROXIDE IS A STRONG BASE. IF IT COMES INTO CONTACT WITH SKIN, FLUSH IMMEDIATELY WITH LARGE VOLUMES OF WATER.

200 mL of an approximately 0.1 M NaOH solution will be prepared. Weigh out between 0.7 and 1.0 g of NaOH on the laboratory balance, recording the exact weight. Add to a 200 mL volumetric flask along with enough water to dissolve. Then fill the flask to the mark with water. Mix thoroughly.

Part III. Preparation and testing of a colloid

Dissolve two small crystals of sodium thiosulfate in 5 mL of deionized water in a large clean test tube. Check the solution for the Tyndall effect by holding the test tube in the path of the light from one of the lamps located in the lab. Remember, if you have a true solution it should not exhibit the Tyndall effect. If you notice the scattering of light, it is probably dust particles and your test tube needs to be re-cleaned. Next, add 10 drops of 6 M HCl to the solution of sodium thiosulfate. The reaction which occurs should generate a colloidal suspension of sulfur in water. The reaction equation is

$$S_2O_3^{-2} + 2H^+ \text{ ----> } H_2O + SO_2 + S \qquad (6)$$

Now, check the mixture for the Tyndall effect again. Note: sometimes it requires a few minutes for the reaction to begin.

SOLUTIONS AND COLLOIDS
LABORATORY REPORT

NAME ___________________________

DATE ___________________________

Part I.

A.

SOLUTE	SOLVENT	OBSERVATIONS	SOLUBLE?
methanol	water		
ethanol	water		
n-propanol	water		
n-butanol	water		
NaCl	water		
table sugar	water		
oil	water		
$MgSO_4$	water		
n-octanol	water		

B.

SOLUTE	SOLVENT	OBSERVATIONS	SOLUBLE?
methanol	oil		
ethanol	oil		
n-propanol	oil		
n-butanol	oil		
NaCl	oil		
table sugar	oil		
oil	oil		
$MgSO_4$	oil		
n-octanol	oil		

Part II.

Mass of NaOH + paper: _________

Mass of paper _________

Mass of NaOH ______

Part III. Observations

Thiosulfate solution:

Thiosulfate + HCl:

QUESTIONS

Part I.

1. Methanol, ethanol, propanol, butanol, and octanol are in a class of compounds called alcohols. Given the following information, prepare a graph of the number of carbon atoms in the compound vs. the boiling point of the compound. Be sure to use the rules for graphs given in Lab 7. Do you see a relationship? What is it?

Compound	Boiling Point
methanol	64.7EC
ethanol	78.5EC
n-propanol	97.2EC
n-butanol	117EC
n-octanol	194EC

2. Which compounds are soluble in water? In oil?

3. What is the relationship between the number of carbon atoms in an alcohol and its solubility?

4. Predict whether ethanol will be soluble in propanol and justify your prediction.

Part II.
5. Calculate the molarity of your solution of NaOH, using the weight obtained in Part II. Show all your work and be sure to give your answer with the appropriate number of significant figures. (Volumetric glassware measures volume to 4 significant figures.)

Part III.
6. Was the thiosulfate before addition of HCl colloidal or a true solution? How do you know? What about after addition of HCl?

7. Explain why you should use your low beam headlights in foggy weather.