SOLUTIONS
EXPERIMENT 13

OBJECTIVE

The objective of this experiment is to demonstrate the concepts of concentrations of solutions and the properties of solution. Colloids will be demonstrated.

EQUIPMENT AND CHEMICALS

Potassium nitrate (KNO_3)
Sodium chloride (NaCl, coarse)
Sodium chloride (NaCl, ground)
Toluene (C_7H_8)
Sugar cubes
Stirring rod
Beaker (250 ml)
Ring stand
Bunsen burner
Stopper
Graduated cylinder (100 ml)
Test tubes (large and small)
Balance
Flask (125 ml)

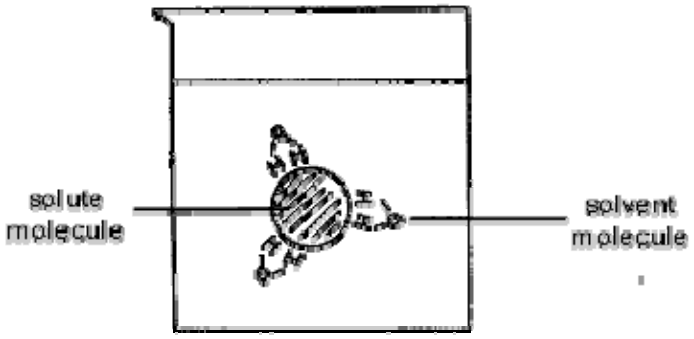
DISCUSSION

Solutions are homogeneous mixtures that are composed of two or more substances. The substances in the solution are of variable amounts within certain limits. The solution has two main parts:

1) the solute which is the least quantity
2) the solvent which is in greater quantity.

For example, if 2 grams of salt is dissolved in 1000 ml of water, the salt is the solute (smaller amount) and the water is the solvent (larger amount). The name of the solution would be a salt solution (named after the solute).

In solutions, the solute molecules (ions) are weakly bound to the solvent molecules.



Solute Molecule Weakly Bound to Solvent Molecules

Solutions can exist in all the states of matter (liquid, gas, solid). The most common types are:

- gas in a liquid (soda water)
- liquid in a liquid (rum and coke)
- solid in a liquid (sugared coffee)
- solid in a solid (stainless steel)
- liquid in a solid (dental fillings)

FACTORS AFFECTING SOLUBILITY

The actual solubility of a solute in a solvent is dependent on three factors:

- the properties of the solvent and solute
- pressure
- temperature

PROPERTIES OF SOLVENT AND SOLUTE

Solutes are held in solution by the attraction of the solute molecule to the solvent molecule

"Like dissolves like" is a frequently used term. Nonpolar solvents normally dissolve covalent solutes and polar solvents normally dissolve ionic compounds. For example, dry cleaners use nonpolar chlorinated hydrocarbons (CCl_4) to remove covalent fats and oils. NaCl, an ionic compound, readily dissolves in water that is polar.

TEMPERATURE

The solubility of a gas in a liquid decreases with an increase in temperature. This is why beer goes "flat" when it gets warm. The solubility of a solid or liquid in a liquid usually increases with an increase in temperature. This is why sugar dissolves in hot tea more readily than ice tea.

PRESSURE

Solutions of liquids and solids are not greatly affected by pressure. Solutions of gases in liquids are greatly affected by pressure. The solubility of a gas is directly proportional to the pressure of that gas above the surface of the liquid (Henry's Law). This is why a cold beer still goes "flat" once it is opened. The CO_2 in the beer escapes to the atmosphere in an attempt to get as much CO_2 in the air as in the beer. Carbonated beverages in partially used bottles will fill the empty section of the bottle with CO_2 until there is an equal amount of CO_2 in the space above the liquid as in the liquid. This is why unused portions of carbonated beverages do not seem as carbonated as when initially opened.

RATE OF SOLUTION

The rate at which a solute dissolves in a liquid is

- rate of stirring
- temperature
- particle size

RATE OF STIRRING

The speed (rate) at which a solute dissolves in a solvent is increased by stirring. The stirring causes more unbound solvent to be available to bind solute molecules faster. The stirring moves the bound solute-solvent away and replaces it with pure solvent that is ready to be attached to a solute particle. This is why stirring your coffee increases the rate at which your sugar dissolves.

TEMPERATURE

An increase in temperature increases the rate at which the solute dissolves in the solvent. The increased temperature causes the particles to move more rapidly (like stirring) and helps the solute particles break away from the other solute particles more readily. This is why it is easier to add sugar to the hot tea than to let the tea cool before adding sugar.

SATURATED, UNSATURATED, AND SUPERSATURATED SOLUTIONS

A saturated solution is one that has the solute dissolving into the solution at the same rate as the solute is coming out of solution (equilibrium). At this point no more solute can be added to the solution (if temperature and pressure is not varied). To prepare a saturated solution, the solute is added until it will no longer dissolve and slight excess is left on the bottom.

An unsaturated solution is one that the concentration (amount) of solute is less than a saturated solution under the same conditions. If more solute can still be dissolved, the solution is unsaturated. A supersaturated solution is one in which the concentration of solute is greater than normally found in a saturated solution under the same conditions. These solutions are unstable and the excess will easily come out to form a saturated solution.

CONCENTRATION OF SOLUTIONS

Two general terms used for solutions are concentrated and dilute. These terms are relative, meaning they are based on a particular solution.

What is concentrated (large amount) in one type of solution can be dilute (small amount) in another type of solution.

Two more quantitative terms (exact amount) are % by mass (volume) and molarity.

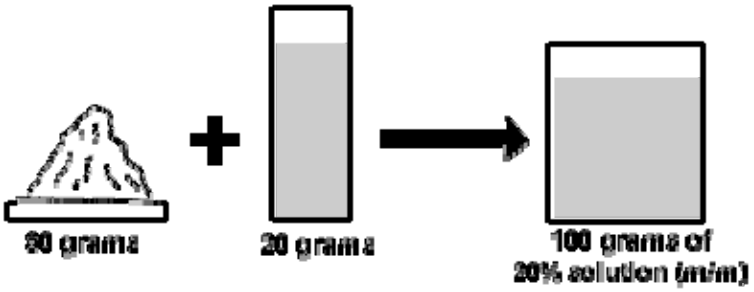
PERCENT BY MASS

The percent by mass of a solute in solution is the weight of the solute divided by the mass of solution (mass of solute + mass of solvent) based on 100.

$$\% \text{ by mass } = \frac{\text{mass of solute}}{\text{mass of solution}} \text{ x } 100$$

The mass of the solution is equal to the mass of the solvent plus the mass of the solute.

$$\text{mass of solution } = \text{ mass of solute} + \text{mass of solvent}$$



Example: Calculate the % by mass of sugar in coffee, in which 30 grams of sugar is added to 170 grams of coffee.

$$\% \text{ mass of coffee } = \frac{\text{mass of sugar}}{\text{mass of solution}} \text{ x } 100$$

$$\text{mass of solution } = \text{ mass of sugar} + \text{mass of coffee}$$

$$\text{mass of solution } = 30 \text{ grams of sugar} + 170 \text{ grams of coffee } = 200 \text{ grams}$$

$$\% \text{ mass of coffee } = \frac{\text{mass of sugar}}{\text{mass of solution}} \text{ x } 100 = \frac{30 \text{ grams}}{200 \text{ grams}} \text{ x } 100 = 15\%$$

Example: Calculate the % salt in seawater if all the water is removed. The weight of the seawater is 200 grams and the mass of the salt remaining after evaporating all the water is 20 grams.

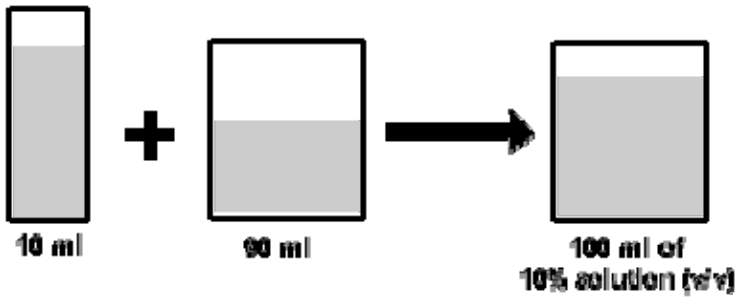
$$\% \text{ salt } = \frac{\text{mass of solute}}{\text{mass of solution}} \text{ x } 100 = \frac{20 \text{ grams of salt}}{200 \text{ grams of solution}} \text{ x } 100 = 10\%$$

PERCENT BY VOLUME

A term closely related to % by mass is known as % by volume. This term is usually used in expressing the concentration of liquids in liquids.

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

$$\text{volume of solution} = \text{volume of solute} + \text{volume of solvent}$$



Example: Calculate the % by volume of alcohol in wine if one liter contains 140 ml of alcohol.

$$\%\ \text{of alcohol} = \frac{\text{volume of alcohol}}{\text{volume of wine}} \times 100$$

$$\%\ \text{of alcohol} = \frac{\text{volume of alcohol}}{\text{volume of wine}} \times 100 = \frac{\text{140 ml of alcohol}}{\text{1000 ml of wine}} \times 100 = 14\%$$

MOLARITY

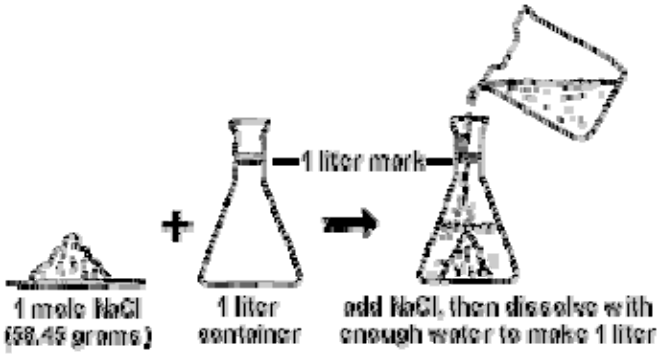
In chemistry a common term for the concentration of solutions is called molarity. Molarity is defined as the number of moles solute per liter of solution.

$$\text{Molarity} = \frac{\text{moles of alcohol}}{\text{liters of solution}}$$

To make a 1 M solution of NaCl, one mole of NaCl is weighed out on a balance.

$$1\ \text{mole} = \text{formula mass of NaCl} = 58.45\ \text{grams}$$

The NaCl is then dissolved in water and the total volume (including the dissolved NaCl) is diluted to exactly one liter (1000 ml).



Example: Calculate the molarity of 80 grams of NaOH in 500 ml of H_20. The formula weight of NaOH = 40 amu.

$$\text{moles of NaOH} = \frac{\text{grams of NaOH}}{\text{formula mass of NaOH}} = \frac{\text{80 g of NaOH}}{\text{40 amu}} = \text{2 moles}$$

$$\text{liters of solution} = \frac{\text{ml of solution}}{\text{1000 ml}} = \frac{\text{500 ml of solution}}{\text{1000 ml}} = \text{0.5 liters}$$

$$\text{molarity of NaOH} = \frac{\text{moles of NaOH}}{\text{liters of solution}} = \frac{\text{2 moles of NaOH}}{\text{0.5 liters of solution}} = \text{4 M NaOH}$$

COLLOIDS

In colloids, the particles are dispersed within the solution without appreciable binding of the solute to the solvent molecules. The solute does not settle out of the solution. Colloids are not true solutions.

Particles	Medium	Name	Example
Gas	Liquid	Foam	Shaving Cream
Gas	Solid	Solid foam	Styrofoam
Liquid	Gas	Liquid aerosol	Fog
Liquid	Liquid	Emulsion	Mayonnaise
Liquid	Solid	Gel	Jello
Solid	Gas	Smoke	Dust
Solid	Liquid	Solid	Paints
Solid	Solid	Solid gel	Gems

PROCEDURE

PART A - CONCENTRATION OF SOLUTIONS

Two of the more common methods of expressing the concentration of solutions are percent by mass and molarity.

Percent By Mass

A 10% by mass solution of potassium nitrate (KNO_3) will be made and the % by mass of an unknown solution will be determined.

1. Weight out 10.0 grams of KNO_3 and transfer to a 250 ml beaker. Record this mass of the Report Sheet.

2. Weigh a 100 ml graduated cylinder and record this mass on the Report Sheet.

3. Fill the graduated cylinder with 80 ml of water and reweigh the cylinder. Report this mass on the Report Sheet.

4. Pour the water in the beaker that contains the KNO_3, dissolve, and calculate the % by mass of KNO_3 on your Report Sheet.

5. Obtain an unknown NaCl solution from your instructor. Record the unknown number on your Report Sheet.

6. Weigh a 250 ml beaker and record the mass of the Report Sheet.

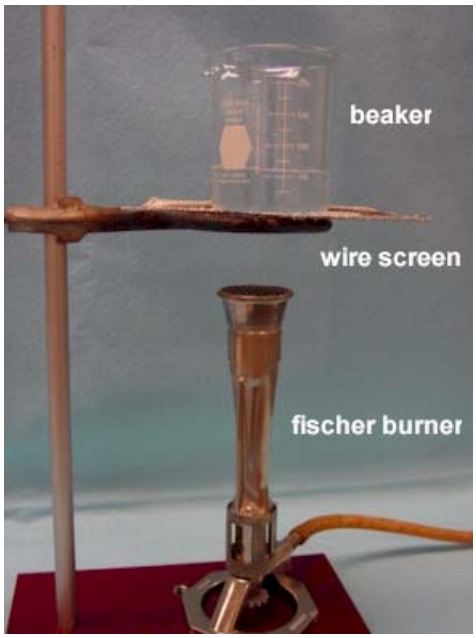
7. Using a graduated cylinder measure out as accurately as possible 50 ml of NaCl solution.

8. Transfer all of the solution to the 250 ml beaker and weigh. Record the mass of the beaker and solution on your Report Sheet.

9. Evaporate the NaCl solution almost to dryness by using low heat. Do not heat fast enough to cause splattering.

10. Increase the heat and bring the NaCl to dryness. Avoid splattering.

11. Weigh and beaker and salt residue and record the mass on the Report Sheet.



12. Calculate the % by weight of the NaCl solution.

$$\% \text{ NaCl} = \frac{\text{mass of salt}}{\text{mass of solution}} \times 100$$

13. The molarity of the solution can also be calculated.

$$\text{molarity of NaCl} = \frac{\text{moles of NaCl}}{\text{liters of solution}}$$

$$\text{moles of NaCl} = \frac{\text{grams of NaCl}}{\text{formula mass of NaCl}}$$

$$\text{liters of solution} = \frac{\text{ml of solution}}{1000 \text{ ml}}$$

14. Calculate the molarity of the NaCl solution of the Report Sheet.

PART B - RATE OF DISSOLVING

The rate at which a solute will dissolve in a solution is affected by three factors:

- stirring
- temperature
- particle size

Stirring

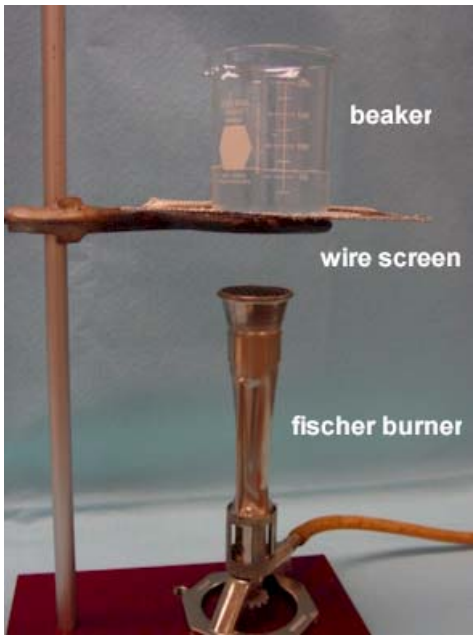
1. Fill two large test tubes with hot water.

2. To each test tube add equal size pieces of rock salt.

3. Stir one test tube with a glass-stirring rod. Do not disturb the other.

4. In which test tube does the salt dissolve fastest? Record your observations on the Report Sheet.

Temperature



1. Fill two test tubes 3/4 full with water and add equal sized pieces of rock salt to each test tube.

2. Place one test tube in boiling water while the other test tube remains at room temperature.

3. In which test tube does the salt dissolve fastest? Record your observations on the Report Sheet.

Particle Size

1. Place a pea size piece of rock salt in a test tube.

2. Place an equal amount of fine table salt in another test tube.

3. Fill both tubes with H_2O and place in boiling water.

4. Which type of NaCl dissolves fastest?

5. Record your observations on the Report Sheet.

PART C - PROPERTIES OF SOLUTE AND SOLVENT

The physical properties of the solute and solvent determine the solubility (like dissolves like).

1. Fill a small test tube l/2 full of water (polar liquid).

2. Fill a small second test tube l/2 full of toluene that is a nonpolar liquid.

3. Add approximately 0.5 grams of fine NaCl to each test tube (NaCl is ionic).

4. Stopper and shake.

5. Observe what happens to the salt in each test tube. Record your observations on Report Sheet.

6. Mix the two solutions and observe what happens to the two solvents and the solute.

PART D - REVIEW QUESTIONS

Complete the review questions on your Report Sheet.

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Name _____
Date _____
Section _____

SOLUTIONS
REPORT
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CONCENTRATION OF SOLUTIONS

Percent by mass of potassium nitrate

1. Mass of KNO_3 _____
2. Mass of cylinder and H_2O _____
3. Mass of cylinder _____
4. Mass of H_20 _____

What is the % by mass of the KNO_3 solution?

Percent by mass of unknown NaCl solution Unknown No. _____

1. Mass of beaker _____
2. Volume of NaCl solution _____
3. Mass of beaker and solution _____
4. Mass of solution _____
5. Mass of beaker and NaCl _____
6. Mass of NaCl _____

Calculate the % by mass of the unknown NaCl solution.

Calculate the molarity of the above NaCl solution.

RATE OF DISSOLVING

Stirring

1. Did the stirred or unstirred salt dissolve first?

2. Based on stirring, what did you conclude form the above result?

Temperature

1. Did the salt in the hot or cold-water dissolve first?

2. Based on temperature, what did you conclude from the above result?

Particle Size

1. Which dissolved first, the fine NaCl or the coarse NaCl (rock salt)?

2. Based on particle size, what do you conclude from the above result?

PROPERTIES OF SOLUTE AND SOLVENT

1. Did the NaCl dissolve in the H_20?

2. Did the NaCl dissolve in the toluene?

3. What happens when you mix the two solutions?

4. Based on the above results, what did you conclude about the properties of solute and solvent?

REVIEW QUESTIONS

1. What are three factors that affect the rate of dissolving?

    a)

    b)

    c)

2. If 5 grams of KCl is dissolved in 45 grams of water, what is the % by mass of the solution?

3. If 58.5 grams of NaCl is diluted to 500 ml, what is the molarity of the NaCl solution?