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Experiment 5 – Properties of Solutions

Discussion

In today's lab, you'll investigate the qualitative nature of solutions. The first step is learning some common terms.

Solute refers to a compound that **dissolves** in a solvent to form a solution. A **solution** can have one or more solutes, but only one solvent. The **solvent** is the compound that is predominant in the solution. A solute is said to be dissolved when it forms a clear, but not necessarily colorless, liquid. Thus, sugar dissolves in water, but fine sand and dust form **suspensions** which are not true solutions.

Solvents can be sorted by their **polarity**. Water is very polar, while benzene, decane, and gasoline are considered **non-polar**. The term organic solvent refers to most solvents other than water that are carbon-containing. Organic solvents can be either polar or non-polar, depending upon their structure. For example, methanol and ethanol are polar organic solvents, while ether and acetone are less polar, and decane and benzene are considered non-polar organic solvents.

Solubility is a measure of how much of a compound can eventually dissolve in a solvent. If a solid does not dissolve, the compound is said to be **insoluble**. It can also be described as slightly soluble, moderately soluble, or very soluble. If the compound is a liquid (not a solid) it can dissolve and is described as **miscible,** or instead forms two layers and is called **immiscible**. Ethanol and water are miscible, while oil and water are immiscible.

Concentration refers to the amount of solute relative to the total volume of solution. A dilute solution has little solute per 100 grams of solution, while a concentrated solution has more solute. A solution is considered saturated when no more solute can dissolve in that solution without it precipitating thereafter.

A supersaturated solution is a solution that holds more solute than it normally can hold at that temperature. Given time, some solute will precipitate out of solution. In other words, the solution is unstable over time.

Concentration can be measured using several terms. "Proof" is used to measure alcohol content in liquor and beer. Chemists tend to use mass percent and molarity which are defined below. Remember that mass percentages range from 0 to 100%, and molarities are generally less than 18 M. Very few compounds can form solutions with higher concentrations.

$$\text{Mass Percent of } \mathbf{X} = \frac{\text{mass of } \mathbf{X}}{\text{mass of } \mathbf{X} + \text{mass of solvent}} \times 100\ \%$$

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Procedure

A. Concentration of a Saturated Solution.

In this section, you'll figure out how many grams of potassium chloride per mL of solution were present in a pre-made saturated solution of KCl.

1. Weigh a clean, dry evaporating dish. In this dish, add 6.0 mL of solution and weigh again. Place the dish in a 250-mL beaker of boiling water. Evaporate the solution until a white solid is present in the dish. Don't let the boiling water bath go dry. This step will take approximately half an hour.

2. Remove the dish from the boiling water with tongs. Place the dish on a wire mesh and gently heat with a Bunsen burner. If you heat too strongly, the solid may "pop" and you will lose some.

3. Let the dish cool until it can be touched safely. Weigh the dish to find out how many grams of potassium chloride are present.

Cleanup: Wash the solid down the drain.

B. Relative Solubility of a Solute

In this section, you will determine whether iodine, a reddish solid, dissolves better in water or decane.

1. Take a test tube and add about 5 mL of water and 2 mL of decane. Stopper the test tube and give it a gentle shake. Note which layer was on top.

2. To this tube, add 5 mL of saturated iodine-water solution. Gently shake again and see which layer has more color.

Cleanup: Empty the test tube into the waste labeled "Decane Waste".

C. Miscibility of Liquids

In this section, you will find out what liquids are miscible with water.

Take three dry test tubes and add the following pair of liquids. Stopper the test tubes and gently shake them. Are there two layers or one?

1. 1 mL of kerosene and 1 mL of isopropyl alcohol
2. 1 mL of kerosene and 1 mL of water
3. 1 mL of isopropyl alcohol and 1 mL of water

Dispose of the first two kerosene mixtures in the "Kerosene Waste" container.

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D. Effect of Particle Size on Rate of Dissolution

1. Fill a test tube with about 0.5 cm of fine crystals of sodium chloride. Fill a second test tube with about 0.5 cm of coarse crystals of sodium chloride. Add 10 mL of water to each tube and shake both tubes an equal number of times. Shake both tubes equally. Time how long it takes to dissolve each.

These solutions can be disposed of down the sink.

E. Effect of Temperature on Dissolution

1. Weigh out two 0.5 g samples of fine sodium chloride crystals. Take two 250-mL beakers and add 50 mL of water to them. Heat one of the beakers to boiling, then let it cool for one minute.

2. Add the salt samples to each beaker and time how long it takes to dissolve each.

3. As soon as the salt dissolves, gently swirl the hot water and observe the denser salt layer in the bottom of the flask. Repeat the process with the cold water.

   These solutions can be disposed of down the sink.

F. Solubility versus Temperature; Saturated and Unsaturated Solutions

1. Weigh out 1.0 g of NaCl and 1.0 g of NH_4Cl and place them in separate, labeled test tubes and add 5 mL of water. Stopper the test tubes and shake the tubes until the salts dissolve.

2. Add another 1.4 g of NaCl to the NaCl solution, and another 1.4 g of NH_4Cl to the NH_4Cl solution. Stopper and shake the tubes for 3 minutes. Note whether or not the salts dissolved.

3. Remove the stoppers and place both tubes in a beaker of boiling water, gently shaking occasionally, and note the results after 5 minutes.

4. Remove the tubes and cool with running tap water for one minute and record your observations. Let the solutions stand for a few minutes and record your observations.

Pour the solutions down the drain.

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G. Ionic Reactions in Solution

1. Place a small lump of pea-sized quantities of a) barium chloride, b) sodium sulfate, c) sodium chloride, and d) barium sulfate into four separate labeled test tubes.

2. Add 5 mL of water, stopper the tubes, and shake them. Which sample(s) do(es) not dissolve?

3. Mix the barium chloride and sodium sulfate together and note the results.

4. Write an equation that describes the results of these test tubes being mixed.

Dispose of all solutions in the “Barium waste” container.

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Data and Calculations for Experiment 5

A. Concentration of a Saturated Solution (record all masses as x.xxx g)

1. a) Mass of evaporating dish ______________

   b) Mass of evap. dish and potassium chloride solution ______________

   c) Mass of evap. dish and residue ______________

2. Calculate: (show setups)
   a) Mass of potassium chloride solution ______________

   b) Mass of residue ______________

   c) Mass of water in potassium chloride solution

   ____

   d) Mass percent of potassium chloride in the solution

   ____

   e) Grams of potassium chloride per 100 g of water in the solution

   ____

B. Relative Solubility of a Solute in Two Solvents

1. a) Which liquid is denser, decane or water? ______________

   b) How did you decide which layer was water?

2. What is the color of iodine in water? ______________

   What is the color of iodine in decane? ______________

3. Which solvent dissolves more iodine? How did you decide this?

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C. Miscibility of Liquids

1. Which liquids were miscible with each other?

2. Which liquids were immiscible with each other?

D. Particle Size and Dissolution Rates

1. How long did it take the fine salt crystals to dissolve?

2. How long did it take the coarse salt crystals to dissolve?

3. Based on these observations, how does particle size affect the rate at which a substance is able to dissolve?

E. Temperature and Dissolution Rates

1. How long did it take the salt crystals to dissolve in hot water?

2. How long did it take the salt crystals to dissolve in cold water?

3. Based on these observations, how does temperature affect the rate at which a substance is able to dissolve?

F. Temperature and Solubility

1. Was the solution with 1.0 g of NaCl in 5.0 mL water saturated at room temperature?

2. Was the solution with 1.0 g of NH_4Cl in 5.0 mL water saturated at room temperature?

3. Was the solution with 2.4 g of NaCl in 5.0 mL water saturated at room temperature?

4. Was the solution with 2.4 g of NH_4Cl in 5.0 mL water saturated at room temperature?

5. Which salt was least soluble at higher temperatures?

6. At the higher temperatures, was the NaCl solution saturated?

7. At the higher temperatures, was the NH_4Cl solution saturated?

8. What happened to the NaCl solution when it was cooled back to room temperature?

9. What happened to the NH_4Cl solution when it was cooled back to room temperature?

10. Solubility is defined as the amount of solute that can dissolve in a given quantity of solvent. Based on your observations in this part, how does temperature affect the solubility of solid solutes? Does it affect different substances in identical ways?

G. Ionic Reactions in Solution

1. Write the formulas for the following substances. Include states of matter (e.g. $_{(aq)}$ or $_{(s)}$) based on the results of your experiment:

   barium sulfate ________________________

   barium chloride ________________________

   sodium sulfate ________________________

   sodium chloride ________________________

2. Write the equation that shows the reaction of barium chloride and sodium sulfate. Use state indicators (e.g. $_{(aq)}$ or $_{(s)}$) for all compounds.

3. Which compound is the white precipitate? How do you know this?