Factors Affecting Solution Formation
An Inquiry-Based Approach

Introduction

Copper sulfate, a crystalline blue solid that readily dissolves in water, is an important agricultural chemical. In solid form the compound is mixed into animal feeds to prevent copper deficiency in farm animals. Solutions of copper sulfate are sprayed on plants, including wheat, potatoes, tomatoes, grapes, and citrus fruits, to control fungus diseases. Although copper sulfate is soluble in water, the rate at which it dissolves can be fast or slow, depending on conditions. What factors affect the rate at which an ionic solid dissolves in water?

Concepts

- Solution
- Solubility
- Solute
- Solvent

Background

A solution is a mixture of two or more pure substances that is homogeneous or uniform throughout. The substance that is being dissolved is called the solute, and the substance that does the dissolving is called the solvent. Solubility, defined as the amount of solute that will dissolve in a given amount of solvent at a particular temperature, depends on the nature of the solute and the solvent and how they interact. Although the solubility of a compound governs how much solute may dissolve, it does not predict how fast the solute will dissolve. Some of the factors that may affect the rate at which a solid will dissolve in a liquid are the particle size of the solid, the temperature of the solvent, the amount of stirring or agitation of the mixture, how much solute is already dissolved in the solvent, and the presence of other dissolved solutes.

The process of an ionic solute dissolving in water is a surface phenomenon. Free-moving water molecules randomly collide with ions on the surface of the solid. The water molecules interact with the ions by means of ion-dipole attractive forces and gradually "chip" away at the surface ions, helping to separate them from the bulk crystal. As the surface ions dissolve, the next layer of ions becomes the new surface layer. This interaction at the surface of a crystal continues until the crystal is completely dissolved or until the solution can accept no more solute.

Understanding the way in which an ionic solute dissolves can help us design conditions to optimize the rate at which the solid dissolves.

Experiment Overview

The purpose of this inquiry-based activity is to investigate the effects of crystal size, degree of mixing, and temperature on the rate at which copper(II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$) dissolves in water.

e-Lab Questions

1. Use the "surface model" described in the *Background* to predict how changing each of the following variables will change how fast a crystalline ionic compound dissolves in water: (a) amount of stirring or agitation; (b) temperature of water; (c) size of the crystals.

2. Outline a series of tests to determine how each variable will affect the rate at which copper(II) sulfate pentahydrate dissolves in water. Each test should look at the effect of changing only one variable at a time—all of the other variables must be controlled or held constant for comparison.

3. Read the *Materials* section and the recommended *Safety Precautions*. Write a step-by-step procedure for the experiment, including any safety precautions that must be followed. *Note:* There are two crystal sizes of copper sulfate. Use about 0.2 g of the fine crystal grade as the control variable. Fill the test tubes about one-third full with distilled or deionized water.

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Copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, fine crystals, 1–2 g
Copper(II) sulfate, $CuSO_4 \cdot 5H_2O$, crystal lumps, 0.2 g
Distilled or deionized water
Ice
Balance, centigram (0.01 g) precision
Beakers, 100-mL, 2
Graduated cylinder, 10- or 25-mL
Hot plate or hot water
Mortar and pestle
Spatula
Stirring rod (optional)
Stoppers to fit test tubes, 3 (optional)
Test tubes, large, 3
Test tube clamp
Test tube rack
Thermometer
Timer
Weighing paper or dishes

afety Precautions

Copper(II) sulfate is moderately toxic by ingestion and is a skin and respiratory tract irritant. Avoid contact with skin and eyes. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the laboratory.

rocedure

1. Verify the procedure with your instructor and review all safety precautions.

2. Carry out the procedure and record all data in a suitable data table.

3. Answer the following *Post-Lab Questions*.

Post-Lab Questions

1. What effect did mixing or shaking have on the rate at which the solute dissolved in water? Give specific evidence from your tests and explain in terms of the "surface model" for solution formation.

2. How did increasing the temperature of the solvent change the rate at which copper sulfate dissolved in water? Was the opposite effect observed when copper sulfate was dissolved in cold water?

3. Use the definition of temperature and the kinetic theory to explain the effect of temperature on the rate of solution formation for copper sulfate.

4. In some cases, increasing the temperature may be a disadvantage in preparing a solution. Suggest a possible case where heating the solution might be a problem.

5. What was the effect of crystal size on the rate of dissolving? How do these results support the surface model for solution formation?

6. Use the results of this experiment to predict how the rate of dissolving would be affected if you tried to dissolve more copper sulfate in a solution that already contained some copper sulfate rather than in distilled water. *Note:* Assume that the total (combined) amount of solute is less than the solubility limit of copper sulfate.

7. Write a short paragraph describing an optimum procedure for preparing a solution.