Lab 3. Rate of Dissolution: Why Do the Surface Area of the Solute, the Temperature of the Solvent, and the Amount of Agitation That Occurs When the Solute and the Solvent Are Mixed Affect the Rate of Dissolution?

Introduction

A solution is a uniform mixture of two or more pure substances. The substance that is dissolved is called the solute, and the substance that does the dissolving is called the solvent. When a solid dissolves in a solvent, it is assumed that the solid dissociates into the elementary particles that make up that solid. The type of elementary particle depends on the nature of the solid. A covalent compound will dissociate into individual molecules when it is added to water, whereas an ionic compound will dissociate into positive and negative ions.

Copper(II) sulfate is an example of a substance that dissolves in water. Copper(II) sulfate is an ionic compound with the chemical formula $CuSO_4$. When it is added to water it dissociates into Cu^{2+} and SO_4^{2-} ions. Copper(II) sulfate is an important agricultural chemical. Solution of copper(II) sulfate is often sprayed on plants, including wheat, potatoes, tomatoes, grapes, and citrus fruits, to help prevent fungal diseases.

Solubility, which is 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 how it interacts with the solvent. For example, 47.93 g of copper(II) sulfate will dissolve in 100 grams of water at 70°C, but only 37.46 g of sodium chloride (NaCl) will dissolve in the same amount and temperature of water. The rate of dissolution, in contrast, is a measure of how fast a solute dissolves in a solvent. There are three factors that affect the rate of dissolution: (1) the surface area of the solute, (2) the temperature of the solvent, and (3) the amount of agitation that occurs when the solute and the solvent are mixed.

To create large amounts of solutions in short periods of time, it is important to understand not only how much of a solute will dissolve in a solvent at a given temperature but also why different factors affect how fast it will dissolve. You will therefore explore three factors that affect the rate of dissolution of copper(II) sulfate and then develop a conceptual model that you can use to explain your observations and predict the dissolution rates of other solutes under different conditions.

Your Task

Determine how the surface area of the solute, the temperature of the solvent, and the amount of agitation that occurs when the solute and the solvent are mixed affect the rate that copper(II) sulfate dissolves in water. Then develop a conceptual model that can be used to explain *why* these factors influence the rate of dissolution. Once you have developed your conceptual model, you will need to test it to determine if it allows you to predict the dissolution rate of another solute under various conditions.

The guiding question of this investigation is, **Why do the surface area of the solute, the temperature of the solvent, and the amount of agitation that occurs when the solute and the solvent are mixed affect the rate of dissolution?**

Materials

You may use any of the following materials during your investigation:

Consumables	Equipment
• $CuSO_4$—powder • $CuSO_4$—fine crystal • $CuSO_4$—medium crystal • Rock candy	• Stopwatch • Hot plate • Electronic or triple beam balance • Stirring rod or magnetic stirrer • 1 Graduated cylinder (50 ml) • 2 Beakers (each 250 ml) • 4 Beakers or Erlenmeyer flasks (each 50 or 100 ml) • Thermometer or temperature probe • Spatula or chemical scoop • Weighing paper or dishes • Mortar and pestle

Safety Precautions

Follow all normal lab safety rules. Copper(II) sulfate is a skin and respiratory irritant and is moderately toxic by ingestion and inhalation. Your teacher will provide important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles and chemical-resistant gloves and apron while in the laboratory.
- Never taste any of the chemicals (including the rock candy).
- Handle all glassware with care.
- Use caution when working with hot plates because they can burn skin. Hot plates also need to be kept away from water and other liquids.
- Wash your hands with soap and water before leaving the laboratory.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

The first step in developing your model is to design and carry out a series of experiments to determine how the surface area of the solute, the temperature of the solvent, and the amount of agitation that occurs when the solute and solvent are mixed affect the rate of dissolution of copper(II) sulfate. To conduct these experiments, you must determine what type of data you will need to collect, how you will collect the data, and how you will analyze the data to answer the guiding question.

To determine *what type of data you need to collect*, think about the following questions:

- What type of measurements or observations will you need to record during each experiment?
- When will you need to make these measurements or observations?

To determine *how you will collect the data*, think about the following questions:

- What will serve as your independent variable?
- How will you vary the independent variable while holding other variables constant?
- What types of comparisons will you need to make?
- What will you do to reduce measurement error?
- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze the data*, think about the following questions:

- What type of calculations will you need to make?
- What type of graph could you create to help make sense of your data?

Once you have carried out your series of experiments, your group will need to develop a conceptual model to explain why these three factors influence the rate of dissolution in the way that they do. The model also needs to be able to explain the nature of the interactions that are taking place between the solute and the solvent on the submicroscopic level.

The last step in this investigation is to test your model. To accomplish this goal, you can use rock candy to determine if your model leads to accurate predictions about the rates of dissolution for a covalent compound under different conditions. If you can use your model to make accurate predictions about the rate of dissolution of other types of solutes under different conditions, then you will be able to generate the evidence you need to convince others that the conceptual model you developed is valid.

Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

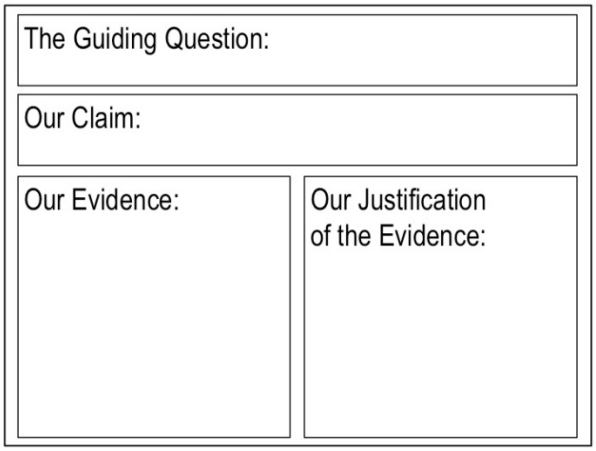
- the importance of developing causal explanations for observations,
- how models are used to help understand natural phenomena,
- the role of imagination and creativity in science, and
- the role of experiments in science.

Initial Argument

Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L3.1.

FIGURE L3.1

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might therefore need to ask the presenter one or more follow-up questions, such as:

- How did your group collect the data? Why did you use that method?
- What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?

- What did your group do to analyze the data, and why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!