Lab: What’s the Solution?

FOR THE TEACHER

Summary
In this lab students will choose one factor that can affect the rate at which a solute will dissolve into solution – amount of stirring, temperature, or particle size, and will design a procedure that can be used to determine how it will affect rate of solution. Students will identify one of the factors above as the independent variable and will determine how it affects the solubility rate as supported by time required to dissolve the solute.

Grade Level
High and Middle School

Objectives
By the end of this lab, students should be able to
- Use scientific methods to solve investigative questions.
- Plan and implement investigative procedures.
- Determine which factor influences the rate of dissolution most: temperature, agitation, or surface area.

Chemistry Topics
This lab supports students’ understanding of
- Solutions
- Solubility
- Solute
- Solvent

Time
Teacher Preparation: 15 minutes
Lesson: 90 minutes

Materials (note: type and amount of materials will be dependent on procedures written by students)
- test tubes and stoppers
- beakers
- mortars & pestles
- thermometers
- stirring rods
- 100-mL graduated cylinders
- balances
- Sugar cubes (6 – 10 per lab group)
- iced water
- hot water

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- Do not consume lab solutions, even if they’re otherwise edible products.
- Food in the lab should be considered a chemical not for consumption.
- When the lab is complete, liquids may be poured in the waste receptacle provided by the teacher
and all other wastes may be placed in the trash.

- Planned procedure must be approved by teacher before students may begin their experiment.

**Teacher Notes**

- I do this experiment over 2 days, 45 minutes each day. On the first day, introduce the problem and have students discuss factors that might affect the dissolving rate of sugar. As a class, we discuss how to tell whether or not the sugar had dissolved. My students usually decide that it is dissolved when no part of the sugar cube can be seen by the naked eye. Have students work with only one independent variable per group for this activity.
- Time required for solvation will be the dependent variable.
- In this experiment, students will choose one factor to examine – amount of stirring, temperature, or particle size and test it to see how it affects rate of reaction. Be careful to keep all other factors the same except for the independent variable you are testing. All other variables such as amount of water and amount of sugar constants. Students need to make repeated trials for reliability (usually at least three trials)
- I have students plan their experiment on the first day. They write a problem question, hypothesis, list their materials (from the list of possibilities that I have given them), write out their procedures, and create a data table. They also identify their independent variable (agitation, temperature, or particle size) and their dependent variable (time to dissolve) as well as list the controlled variables for their experiment. The students’ hypotheses should be stated as a cause-and-effect relationship. Students should use “If ... then the sugar will dissolve more quickly.” Sample hypotheses might include the following:
  - If the temperature of the water is increased, the sugar will dissolve more quickly.
  - If the temperature of the water is increased, the sugar will dissolve more slowly.
  - If the sugar cube is crushed into crystals, the sugar will dissolve more quickly/slowly.
  - If the water is stirred, the sugar will dissolve more quickly/slowly.
- Students turn in their experimental plan which I examine after class on the first day and critique as needed, especially looking for safety hazards. I hand them back the next day and students must correct major errors before beginning the lab. I make available the materials requested by each group (from the predetermined list of available materials).
- **Expected Experimental Outcomes and Explanations:**
  - **Agitation**, or stirring, makes the solute dissolve more rapidly because it brings fresh solvent into contact with the surface of the solute. Stirring does not have an effect on solubility of a substance but does affect the rate of solution. Many will tell you that a teaspoon of sugar will not dissolve if it is put into tea without any stirring of the tea. Actually, though, if we left the tea to stand for a long enough time, the sugar would dissolve. Stirring only increases the speed of the process because it increases movement of the solvent, exposing solute to fresh portions of it, thus increasing solubility rate. Since molecules in liquid substances are in constant motion, the process would take place anyway, but it would take more time without stirring.
  - **Temperature** can also affect how quickly a solute dissolves in a solvent. Basically, for most solvents, solubility of solid solutes increases with temperature. Temperature increases rate of solution by increasing the kinetic energy and rate of collision of the particles. As the temperature increases, the particles of the solid move faster, and that increases the chances that they will interact with more of the solvent particles. This results in increasing the rate at which a solution occurs. Temperature can also affect the amount of solute that dissolves. In most cases, as the temperature is increased, more solute particles will be dissolved. One recipe for making syrup called for two cups of sugar to be dissolved in one cup of water and after which the maple flavoring was added. Sounds impossible but can be done if the solvent is heated. However, some solutes, such as table salt, are not more soluble in warmer temperatures. The amount of table salt that can be dissolved in ice water is about the same amount that could dissolve in boiling
water. The situation is different for gases though. With increase of the temperature they became less soluble in each other and in water, but more soluble in organic solvents.

- The third factor to consider in regard to rate of solution is particle size. A general rule can be found that larger particles are less soluble than smaller particles. If the pressure, and temperature are the same, and if two solutes have the same polarity, the one with smaller particles is usually more soluble. Smaller particles have more surface area and rate of dissolving increases as surface area increases. Smaller particles can also fit more easily between solvent spaces. If you were to dissolve sugar in water, a sugar cube will dissolve slower than an equal amount of tiny pieces of sugar crystals. The combined surface area of all of the sugar crystals have a much greater surface area than the one sugar cube and will have more contact with the water molecules. This allows the sugar crystals to dissolve much more quickly.

- Differentiation: For lower levels, you might need to give more guidance on the development of procedures for the lab.

**FOR THE STUDENT**

**Lesson**

**What’s the Solution?**

**Background**

A Solution is a type of homogeneous mixture formed when one substance dissolves in another. The particles of the substances that have been mixed are evenly spread throughout. The substance that is dissolved is called the solute and the substance that does the dissolving is called the solvent. Solutes and solvents can be solids, liquids, or gases. One of the most common types of solutions involves a solid dissolved in a liquid. If a substance is soluble in water, it means the substance can dissolve in water. If you were to try to dissolve some sand into a cup of water, the sand would be insoluble. Insoluble means that the substance does not dissolve. If you were to take a teaspoon of table salt or sugar and conduct the same experiment, the result would be different. Salt and sugar are both soluble in water. When a substance is soluble, it means that the substance has the ability to dissolve in another substance. There is a common rule in chemistry that describes if a solution is likely to form: Like dissolves like. Two polar substances should dissolve. Two nonpolar substances should dissolve. A polar and a nonpolar substance should not dissolve. You will use solid sugar (in the form of a sugar cube) as your solute and water as the solvent into which it will be solvated to ensure that it will be able to form a solution.

There are several factors that affect the rate of solution, or how quickly a solute dissolves. The surface area of the solute particles, the size of the solute particles, temperature, type of solvent, amount of shaking/stirring or agitation, and amount of solvent can all affect how quickly substances will mix. In this experiment, you will choose one factor to examine: amount of stirring, temperature, or particle size and test it to see how it affects rate of reaction. Be careful to keep all other factors the same except for the independent variable you are testing. All other variables are referred to as constants. You will need to make repeated trials for reliability.

Agitation or stirring is one possible variable that you could test. Many will tell you that a teaspoon of sugar will not dissolve if it is put into tea without any stirring of the tea. Stirring increases movement of the solvent, exposing solute to fresh portions of it. However, since molecules in liquid substances are in constant motion, the process should take place anyway, even without stirring.
Temperature is another variable that could be tested to see how it affects the solubility rate. Increased temperature can affect the amount of solute that dissolves because increasing temperature increases the kinetic energy and rate of collision of the particles, which also increases the chances that they will interact with more of the solvent particles. One recipe for making syrup called for two cups of sugar to be dissolved in one cup of water and after which the maple flavoring was added. Sounds impossible but can be done if the solvent is heated. However, some solutes, such as table salt, are not more soluble in warmer temperatures. The amount of table salt that can be dissolved in ice water is about the same amount that could dissolve in boiling water. So temperature can affect the amount of solute that dissolves but can it also increase the rate at which a solute dissolves?

The third factor to consider in regard to rate of solution is particle size. Smaller particles have more surface area. If you were to compare a sugar cube to an equal amount of sugar, the combined surface area of all of the sugar crystals have a much greater surface area than the one sugar cube and will have more contact with the water molecules. How will this affect rate of solution?

In this activity you will:
1. Identify three factors that affect the rate at which a solute dissolves in a solvent.
2. Design an experiment to test the effect of one of these factors on the rate at which salt or sugar crystals dissolve in water.
3. Create a data table that includes space for all variable levels and trials.

Pre-lab
1. As a group, decide which variable will be your independent variable (variable to test). Write a hypothesis predicting how your independent variable will influence the rate of solution, using correct format as shown in the samples below.
   - If the temperature of the water is increased, the sugar will dissolve more quickly.
   - If the temperature of the water is increased, the sugar will dissolve more slowly.
   - If the temperature of water is increased, it will not affect the solvation rate of sugar.
2. List all the materials that you will need, being specific about how much of each item you will need.
3. Design a step-by-step procedure to test your independent variable. You don’t need to include tiny details, but be specific enough so that someone else would be able to repeat what you did. Remember to have a control, maintain constants, and run repeated trials. You will be limited to only using 30 mL of solvent. Make sure to identify safety procedures that will be followed.
4. Create a data table that includes space for all variable levels and trials. You also need to include an appropriate title for your data table (one that describes the data being collected) and units of measurement.

Note: This experimental procedure and other pre-lab tasks must be approved before you can begin working on the lab. You will complete it on day one, turn it to the teacher for approval, make any revisions suggested by the teacher when you get it back on day two, and only then, may you begin the process you described to test your hypothesis. You will have only one period to plan and one period to complete the lab.
Objective
Identify three factors that affect the rate at which a solute dissolves in a solvent and design an experiment to test the effect of one of these factors on the rate at which a sugar cube dissolves in water.

Materials (from which your team can select)
- test tubes and stoppers
- beakers
- mortars & pestles
- thermometers
- stirring rods
- timer
- iced water
- hot water
- 100-mL graduated cylinders
- balances
- sugar cubes (6–10 per group)

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Do not consume lab solutions, even if they’re otherwise edible products.
- Food in the lab should be considered a chemical not for consumption.
- When the lab is complete, liquids may be poured in the waste receptacle provided by the teacher and all other wastes may be placed in the trash.
- Planned procedure must be approved by teacher before you may begin your experiment.

Procedure
1. Design an inquiry investigation using sugar cubes and water. Sample problem questions could include:
   - How does temperature affect the time it takes for a sugar cube to dissolve?
   - How does stirring or agitation affect the time it takes it to dissolve a sugar cube?
   - How does the particle size of sugar affect the time it takes it to dissolve?
2. Write a hypothesis predicting how your independent variable will influence the rate of solution. (Will the solute dissolve faster or slower?)
3. Design a step-by-step procedure to test your independent variable. You don’t need to include every small detail, but be specific enough so that someone else would be able to repeat what you did. Remember to have a control, maintain constants, and run repeated trials.
4. Create an appropriate data table that includes space for all variable levels and trials. You also need to include an appropriate title (one that describes the data being collected) and units of measurement.
5. The procedure must be approved by the teacher before you begin working and should be recorded in the secretary’s notebook.

Data (sample)

<table>
<thead>
<tr>
<th>Trial</th>
<th>Hot Water</th>
<th>Cold water</th>
<th>Room Temp water (control)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Note: Everything up to this point should be completed on day one of the experiment. On day two you will make recommended changes, complete the experiment, record data, and complete the analysis questions and conclusion.

Analysis Questions
1. What are the three factors that can influence the rate at which a solute dissolves in a solvent?
2. How many trials were tested? Why do scientists often test several trials of an experiment?
3. What do you think was the most important constant in the experiment? Why?
4. Why is it important to have only one independent variable in an experiment?
5. Describe one real-life circumstance where understanding how the independent variable affects the dissolving rate of a solute might be useful.

Conclusion
Summarize what you learned in this lesson. Address the following questions:
- What were your independent and dependent variables in your experiment?
- What variables did you control and why was it necessary to control them?
- Indicate whether your hypothesis was supported or not and summarize the results that you used to make this decision.
- Make a concise statement that describes how your independent variable influenced the rate of solution.