Lab 21: Reaction Rate

Concepts to explore:

- Understand how temperature, surface area, and concentration influence the rate of a reaction
- Relate reaction rates on a molecular level

Introduction

Why is it easier to sweeten hot tea with granular sugar than cold tea with sugar cubes?

As you begin to stir sugar cubes into cold tea, the sugar particles sluggishly separate from the cube while following the flow of your spinning stirrer. Eventually, after much stressful stirring, the little sugar crystals make their way into solution. Then you notice that your friend has almost finished his sweet tea and has already returned for more. You complain that you've been stirring forever just to dissolve the sugar in your cold tea. Your friend responds, "I only had to stir mine for a few seconds, and it was good to drink!" Why do you think your friend's sweet tea was finished so much faster? Well, his sweet tea was made from hot water and granular sugar.

A reaction rate is the time that it takes for the reactants to be changed into products. The rate is given as the change of the concentration of a reactant or product in a certain amount of time, and can be described using various units. Reaction rates are affected by several factors which include the following: the nature of the reactants, surface area, concentration, temperature, pressure, and the presence of a catalyst. Whether a reaction rate will increase or decrease depends on the rate that the molecules involved effectively collide to result in a reaction.

Figure 1: **Calcium carbonate is abundant in nature, and is the primary component of limestone and marble rock (top). Calcium carbonate is commonly found in antacids and calcium supplements.**

Throughout this laboratory exercise, you will use calcium carbonate and citric acid to discover how temperature, surface area, and concentration affect reaction rates. Calcium carbonate is the main compound found in marble. Marble is often used to make statutes or as decorative rock chips in flower beds. Citric acid reacts with calcium carbonate to form calcium chloride, carbon dioxide gas, and water. This is similar to how acid rain degrades marble statutes.

In this laboratory exercise you will compare how two different surface areas of calcium carbonate, a powder and a solid rock piece, react with different concentrations of citric acid at various temperatures. The powder has a large overall surface area due to its many individual parts. In contrast, the solid, a crystallized rock, has a much smaller surface area. You will record how long it takes for each reaction to complete, then calculate and compare the reaction rates.

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Pre-lab Questions

1. Name five factors that can affect the rate of a reaction.

3. In the opening paragraph example, it took more time to make sweet tea with cold water and sugar cubes than to sweeten hot tea with granular sugar. Why?

4. What is the primary factor that determines whether a reaction rate increases or decreases?

Experiment: Comparing Reaction Rates

Materials

Safety Equipment: Safety goggles, gloves
40 mL Saturated citric acid solution (60%)
Calcium Carbonate rock ($CaCO_3$)
Calcium Carbonate powder ($CaCO_3$)
10 mL graduated cylinder
4 test tubes
50 mL beaker
250 mL beaker
Test tube holder
Test tube rack
Baking soda
pH Paper
Permanent marker
Scale
Stopwatch
Stir rod
Distilled water*
Ice*
Boiling water bath*
*You must provide

Procedure

1. Label four test tubes 1, 2, 4, and 5 (Reaction 3 takes place in the 50mL beaker, which is why you number the test tubes this way).
2. Break off a piece of $CaCO_3$ rock with a mass of approximately 0.2 grams. Record the actual mass in the Data section. Place the rock in test tube 1.
3. Weigh out three more pieces of approximately 0.2 grams of $CaCO_3$ rock. These should be as close as possible to the mass of the first rock sample. Place the pieces of rock into test tubes **2, 4 and 5**. Record each of their masses Table 1.
4. Into a 50 mL beaker, weigh out approximately 0.2 grams of $CaCO_3$ powder. This should be as close as possible to the amount of the previously weighed pieces of marble rock. Record the mass in Table 1.

Reaction # 1

6. Measure 10 mL of saturated citric acid solution into a 10 mL graduated cylinder. Transfer the acid to test tube 1 (with the $CaCO_3$ rock), and place this test tube immediately in an ice bath. Record the start time. Check on this reaction frequently and record when the reaction no longer produces bubbles (gas). Record all values in Table 1, along with your observations.

Reaction # 2

6. Measure 5 mL of saturated citric acid solution (60%) into a 10 mL graduated cylinder and dilute to 30% by adding 5 mL distilled water. Transfer the diluted acid to test tube 2, and place this test tube in the rack. Record the start time. Check on this reaction frequently and record the time when the reaction no longer produces bubbles (gas). Record all values in Table 1, along with your observations.

Reaction # 3

6. Measure 5 mL of saturated citric acid solution (60%) into a 10 mL graduated cylinder and dilute it to 30% by adding 5 mL distilled water. Transfer this diluted acid to the 50 mL beaker that contains $CaCO_3$ powder. Use a stopwatch to time the reaction from when the acid is poured onto the powder and until the reaction no longer produces bubbles (gas). Record all values in Table 1, along with your observations.

Reaction # 4

6. Measure 10 mL of saturated citric acid solution into a 10 mL graduated cylinder. Transfer the acid to test tube 4 and place this test tube in the rack**.** Record the starting time. Check on the reaction frequently and record the time when the reaction is no longer fizzing. Record all values in Table 1, along with your observations.

Reaction # 5

6. Measure 10 mL of saturated citric acid solution into a 10 mL graduated cylinder. Transfer the acid to test tube 5, and place this test tube in the previously started hot water bath**.** Record the starting time. Check on this reaction frequently and record the time when the reaction stops (no longer fizzing). Record all values in

Data

Table 1: Reaction rate data and observations

Substance, Reaction #	Variable	Mass of the $CaCO_3$ (g) (these should be close)	Time of the reaction (sec) (start/stop)	% Citric Acid	Observations
$CaCO_3$ Rock #1	Saturated acid solution, iced				
$CaCO_3$ Rock #2	Diluted acid solution, room temp.				
$CaCO_3$ Powder #3	Diluted acid solution, room temp.				
$CaCO_3$ Rock #4	Saturated acid solution, room temp.				
$CaCO_3$ Rock #5	Saturated acid solution, heated				

Calculations

Calculate the rate (g/sec) of each of the reactions you observed.

- Reaction 1 (rock, iced, saturated solution):

- Reaction 2 (rock, room temperature, diluted solution):

- Reaction 3 (powder, room temperature, diluted solution):

- Reaction 4 (rock, room temperature, saturated solution):

- Reaction 5 (rock, heated, saturated solution):

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Post-lab Questions

1. All the reactions that you performed were chemically the same. You just varied several factors. What were the factors that were varied?

2. Which factor do you think made the biggest influence on the reactions? Why?

3. Out of the five different reactions, which reaction was the slowest? Was this what you expected? Why?

4. Why do you think marble statues require long periods of time to degrade in regions that are affected by acid rain?