Scope, Sequence & Coordination

A National Curriculum Development and Evaluation Project for High School Science Education

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National Science Teachers Association

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National Science Education Standard—Physical Science
Chemical Reactions
Chemical reactions can take place in time periods ranging from the few femtoseconds (10^{-15} seconds) required for an atom to move a fraction of a chemical bond distance to geologic time scales of billions of years. Reaction rates depend on how often the reacting atoms and molecules encounter one another, the temperature, and on the properties—including shape—of the reacting species.

Teacher Materials

Learning Sequence Item:

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Factors that Affect Reaction Rates

March 1996
Adapted by:Mohamad Elkhatib and Linda W. Crow

Chemical Reaction Rates. Students should observe several physical and chemical changes that occur at different rates and the factors that affect the rate of such changes: types of reacting substances, surface area of reactants, temperature, and concentration. (*Chemistry, A Framework for High School Science Education, p. 70.)*

Contents

This micro-unit was adapted by **Mohamad Elkhatib** (Davis High School, Houston) and **Linda W. Crow** (Baylor College of Medicine, Houston)

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Learning Sequence

Chemical Reaction Rates. Students should observe several physical and chemical changes that occur at different rates and the factors that affect the rate of such changes: types of reacting substances, surface area of reactants, temperature, and concentration. (*Chemistry, A Framework for High School Science Education, p. 70.)*

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
Motion to Dye For **Lab Activity 1** All Stirred Up **Lab Activity 2** Temperature Changes **Lab Activity 3** Other Indicators **Lab Activity 4** Observing Individual Molecular Reactions **Reading 3** Reaction rates: Liquids & Solids **Assessment 8**	Preventing Decay **Reading 2**		The Man Who Found Three Mammoths **Reading 1**

Suggested Sequence of Events

Event #1

Lab Activity

1. Motion to Dye For (20 minutes)

Event #2

Lab Activity

1. All Stirred Up (15 minutes)

Event #3

Lab Activity

3. Temperature Changes (20 minutes)

Event #4

Lab Activity

4. Other Indicators (15 minutes)

Event #5

Readings from Inquiry, Science and Technology, Personal and Social Perspectives, and History of Science. Student should read all of the following:

Reading 1. The Man Who Found Three Mammoths
Reading 2. Preventing Decay
Reading 3. Observing Individual Molecular Reactions

The above readings can be found in the student version of this publication.

Assessment items can be found at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Science as Inquiry

Motion to Dye For

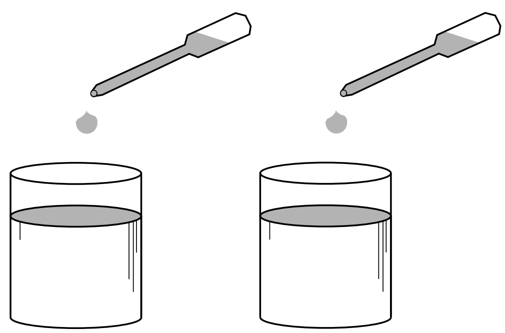
How Does Temperature Affect the Motion of Particles in a Liquid?

Overview:

Students observe the movement of food coloring in hot and cold water.

Materials:

2 tall glass containers (beakers, jars, cylinders, flasks)
hot water
cold water
food coloring or India ink



Procedure:

Students fill a tall container about 3/4 full with very hot water. Then they add the same amount of chilled water to another container. Both containers are allowed to rest for a few moments to decrease “thermal currents.” They then add one drop of food coloring (or ink) to the center of each container and record their observations.

Note: Sometimes the temperature of the food coloring or ink may affect the results of this experiment.

Background:

A drop of dye or ink is used to determine the effects of temperature on particle motion. Particles in a liquid can move around more than particles in a solid. However, their movement has limitations due to the attraction between the particles.

In hot water, the dye particles have more energy and they can move apart faster. The energy is due to the increased temperature of the water. In cold water, the movement is slower, but the dye particles still have a tendency to move apart.

Variations:

Try using water that is not hot or cold. Repeat the experiment. Repeat the experiment using salt water.

Adapted from:
Borgford, Christie L., and Lee R. Summerlin, *Chemical Activities*, American Chemical Society, Washington, D.C., 1988.

Science as Inquiry

All Stirred Up

How Does Stirring Affect Mixing?

Materials:

beaker
3–4 sugar cubes
cold water
stop watch

Procedure:

Students place a sugar cube into a beaker and then add cool tap water. With a stopwatch, they then time how long it takes the sugar cube to dissolve. Challenge them to create at least two methods to speed-up the dissolving time. Have students try those methods and keep records of their trials.

Background:

By stirring and grinding the material into smaller pieces, a larger surface area is created. This larger surface area enhances dissolving and the dissolving time will be shortened. Heating the solution will also decrease the dissolving time.

Variations:

Ask them to invent ways to increase the rate of bubbling of a small amount (25 mL) of a carbonated beverage.

Adapted from:
Unknown.

Science as Inquiry

Temperature Changes

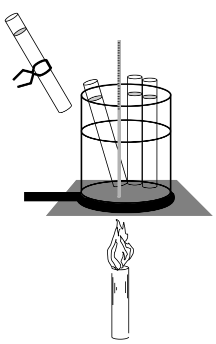
How Does Temperature Affect Reaction Rate?

Overview:

Vinegar at different temperatures with magnesium is used to determine reaction rate changes.

Materials: (for each group)

2 beakers for water bath (250 or 400 mL)
6 test tubes (to fit in beakers)
vinegar
thermometer
12–15 cm magnesium ribbon
hot plate (Bunsen burner)
ice cubes
stopwatch or clock



Procedure:

Before the class begins, cut the magnesium strips into 6 pieces of equal length. Using these strips, have the students perform the following tests in test tubes containing vinegar. In each of these tests, students observe any changes and record the amount of time it takes the strip to react completely with the acetic acid found in the vinegar.

Test 1: Students drop a piece of magnesium into a test tube of vinegar which is at room temperature.

Test 2: Students cool water to 10°C by adding ice cubes. They then place a test tube of vinegar into the water. After two minutes the vinegar should be at thermal equilibrium. Students drop a magnesium strip into the test tube.

Tests 3–6: Students heat water for a water bath. The remaining four test tubes of vinegar are placed into this hot water bath. A thermometer is added to the water. As the temperature increases by 10° increments, a test tube is removed and a magnesium strip is added to the tube. Students repeat this process until all the tubes are used.

After completing these six tests, six time measurements will be recorded. Ask students to construct a graph of temperature (*x* axis) and reaction time (*y* axis).

Background:

During this experiment, the vinegar is heated to determine the effects of heat on the reaction time. An increase in temperature will increase the rate of the reaction and decrease the reaction time. The graph should indicate that the rate doubles when the temperature increase by an increment of 10°.

Variations:

Have students use the same length of strip, but this time cut it into smaller pieces. Repeat the procedure.

Adapted from:
Borgford, Christie L., and Lee R. Summerlin, *Chemical Activities*, American Chemical Society, Washington, D.C., 1988.

Science as Inquiry

Other Indicators

How do Concentration and Temperature Affect a Reaction?

Overview:

Cloudiness is used to measure reaction time.

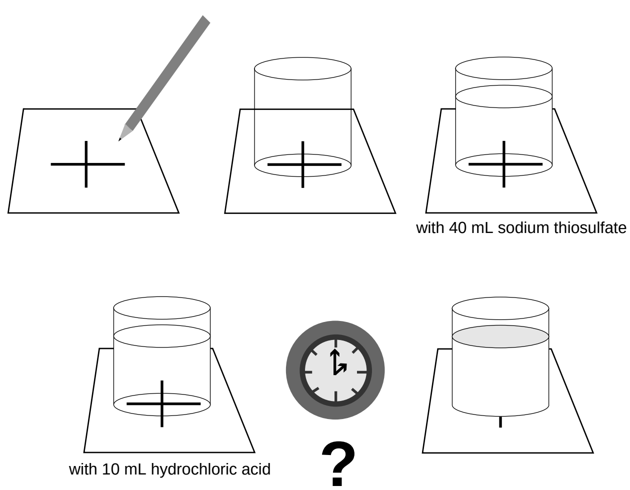
Materials: (for each group)

300 mL of sodium thiosulfate solution (62 grams of sodium thiosulfate and 2500 mL of distilled water)
70 mL of dilute hydrochloric acid (70 mL of concentrated hydrochloric acid and 70 mL of distilled water)
40 mL distilled water
1 beaker, 100 mL
1 graduated cylinder, 100 mL
1 piece of white paper
pencil
stopwatch

Procedure:

Before class begins, prepare the solutions of sodium thiosulfate and hydrochloric acid. To prepare the sodium thiosulfate solution, measure 62 grams of sodium thiosulfate and dissolve it in 2500 mL of distilled water. To prepare dilute hydrochloric acid solution, add 70 mL of concentrated hydrochloric acid to 70 mL of distilled water.

Students draw a cross with a dark pencil on a piece of white paper. Then they place a 100 mL



beaker on the cross and add 40 mL of sodium thiosulfate solution into the beaker. Finally they add 10 mL of hydrochloric acid and time how long it takes for the mixture to begun so cloudy that they can no longer see the cross.

Have them repeat the same experiment two more times, using sodium thiosulfate heated to different temperatures (40° and 60°). Next have them repeat the experiment several times by mixing different amounts of sodium thiosulfate, water and hydrochloric acid (all at room temperature). In each case, the total volume (sodium thiosulfate, water and hydrochloric acid) must equal 50 mL. For example, students could mix 30 mL of sodium thiosulfate with 10 mL of water and 10 mL of hydrochloric acid.

Background:

When sodium thiosulfate is mixed with hydrochloric acid, a reaction occurs and elemental sulfur is produced. This sulfur makes the mixture cloudy. The time it takes for the mixture to become cloudy is the speed or rate of the reaction.

Increases in temperature will generally increase the rate of the reaction and the reaction will occur more quickly. Changing the concentrations of the reactants also has an impact upon the rate of the reaction. The distilled water will dilute the reactants and cause the reaction to occur at a slower rate.

Variations:

Try heating the water before mixing it with the other chemicals.

Adapted from:

Borgford, Christie L., and Lee R. Summerlin, *Chemical Activities*, American Chemical Society, Washington, D.C., 1988.

Science as Inquiry

Lemonade

Item:

You like your lemonade sweet, but you don't like to wait for the sugar to dissolve! Let's do a study on the best way to dissolve sugar. First, you and your team partner should predict how long an unstirred sugar cube will take to dissolve. Here are the rules for this study:

a. Each team will be given a sugar cube to add to 150 mL of water. Watch it dissolve without disturbing it. Time how long it takes. Was your prediction close? Why or why not?

b. Each team must then decide what one variable they will change to see if it speeds up the rate at which the sugar cube dissolves. They should write a plan for this change and state how they are going to be sure nothing else changes.

c. Each team will get a new sugar cube and another 150 mL of water to carry out the plan. In the individual report, answer:

- What was the single variable changed?
- What were the other variables that could have been changed?
- Which of these variables seemed to have the biggest effect?
- What might be different, if anything, about the conditions in the lemonade factory? (They aren't dissolving in pure tap water? Might this make a difference?)
- Based on the class data, what are your recommendations to the lemonade factory?

Science as Inquiry

Solution Rate

Item:

Which of the following will speed up the dissolving of a solid solute in water:

A. Compress the solution into a tablet?
B. Cool the solution?
C. Grind the solute to a powder?
D. Freeze the solute?

Justification:

Based on your answer, explain what is happening to the interaction between the solute and the water particles to cause it to dissolve faster. Explain why the other three would not speed up the process.

Answer:

The high surface area of a powder allows for a great deal of water-solute molecular interaction simultaneously, thus speeding up the solution process. Cooling slows down the particles, making a tablet will have the opposite effect to grinding.

Science as Inquiry

Identify Effects of Change

Item:

Pieces of zinc metal react with hydrochloric acid, producing bubbles of hydrogen gas and a solution of zinc chloride. Which of the following is *not* likely to increase the rate at which this reaction occurs?

A. Grinding the zinc into a powder
B. Diluting the hydrochloric acid
C. Stirring the acid
D. Heating the hydrochloric acid

Justification:

List one way not mentioned above of speeding up this reaction.

Answer:

B. Diluting the HCl will result in a slower reaction.

Science as Inquiry

Zinc Reactions

Item:

For the reaction of zinc metal with hydrochloric acid, explain why:

A. Concentrated hydrochloric acid reacts at a faster rate than dilute hydrochloric acid.
B. Zinc powder reacts faster than pieces of zinc.
C. The reaction occurs faster at 60°C than at 20°C.

Answer:

Science as Inquiry

Crystal Solutions

Item:

Why does crushing a solid cause it to dissolve faster?

Answer:

When solids are made smaller, the surface area increases. Dissolving takes place at the surface of the solid. More surface area allows more solvent to come in contact with more solute, therefore increasing the solution rate.

Science as Inquiry

Speed Up the Rate

Item:

The formation of solutions depends on several factors; surface area of solute, nature of solvent and solute, temperature and other factors. If a student wants to speed up the rate of the solution process, one or more of these factors must be adjusted.

How do the methods of speeding the rate of solution for dissolving a solid in a liquid compare to the methods of speeding the rate of solution when dissolving a gas in a liquid? In each case, explain why:

Answer:

The rate of solution for dissolving a solid in a liquid can be increased by stirring because stirring brings more fresh solvent in contact with more solute. This causes more solute to dissolve faster.

Increasing the surface area of the solid allows more solvent to come in contact with more of the solute, thus increasing the rate of solution.

Increasing the temperature of a solvent speeds up the dissolving process because the speed of the particles increases causing more collisions which will cause the solute particles to break apart faster.

The rate of solution for dissolving a gas in a liquid can be increased by cooling the liquid solvent. Gases are more soluble in cold liquids than in hot or warm liquids. Stirring a solution of this type will cause a decrease in the solution rate because stirring increases the temperature which decreases solubility.

Science as Inquiry

Solubility of Salts

Item:

Chemical reactions—to determine the effects of temperature on the solubility of salts

Materials: table salt, table sugar, calcium acetate, potassium nitrate, four test tubes, stirring rod, burner, test tube holder, test tube rack, safety glasses, and balance. Hint: use the same amount of water and same temperature readings as controls.

Procedure:

Design an experiment that will allow you to test the effects of temperature on the solubility of salts. Test the solubility of each in cold water and warm water. Record all observations in a data chart.

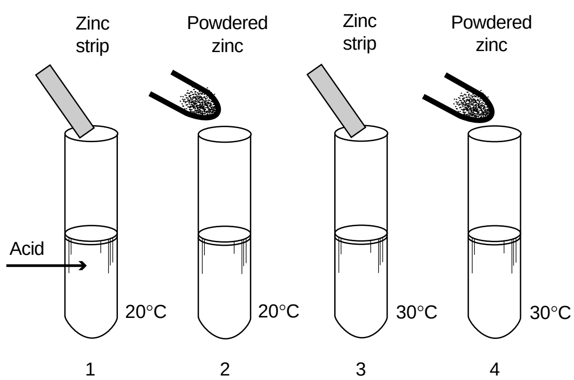
Analysis:

1. What happened to each solid when added to cold water?
2. Did stirring have an effect on the amount or rate at which the solids dissolved?
3. What happened to each solid when the mixture in each test tube was heated?
4. Does the temperature of the liquid have an effect on the solubility of the solid?

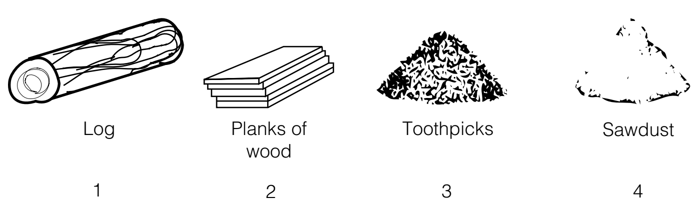
Science as Inquiry

Reaction Rates: Liquids & Solids

Design an experiment to determine the factors that affect the rate at which substances react. Use diagrams to explain the changes that you observed. Hydrogen gas is produced in the chemical reactions illustrated below. Which experiment is most likely to have the fastest reaction rate?



Two of the four test tubes have a temperature of 20°, and 2 have a temperature of 30°. Test Tube A at 20° contains a strip of zinc being suspended from its mouth. Test Tube B at the same temperature shows powdered zinc dust being sprinkled into it. Test Tube C at 30° contains a strip of zinc being suspended from its mouth. Test Tube D at the same temperature shows powdered zinc dust being sprinkled into it. Explain why you chose the diagram that you did.



This diagram shows four samples of wood. Each sample has a mass of one kilogram. Which one would most likely burn the fastest?

Prepare a dialogue between 2 of the molecules that were involved in one of the chemical reactions that you have just observed.

Adapted by C. Heath from:
Cohen, Paul S., Jerry Deutsch, Dr. Anthony V. Sorrentino, *Achieving Competence in Science,* An AMSCO Publication, New York, New York.

Consumables

Item	Quantity (per lab group)	Event
food coloring	4 drops	1
hydrochloric acid, cinc.	70 mL	
magnesium ribbon	12–15 cm	3
paper, white	1	4
sodium thiosulfate	62 g	4
sugar cubes	3–4	2
vinegar	50 mL	3
water, distilled	2500 mL, 70 mL, 40 mL	4
water, hot		1
water, cold		1, 2

Non-Consumables

Item	Quantity (per lab group)	Event
beaker, 250–400 mL	1, 2, 1	2, 3, 4
containers, tall glass	2	1
cylinder, grduated, 100 mL	1	4
ice cubes	2–3	3
pencil	1	4
stopwatch	1	2, 3, 4
test tubes	6	3
thermometer	1	3

Activity Key
1. Motion to Dye For
2. All Stirred Up
3. Temperature Changes
4. Other Indicators