Throughout the guide, teaching tips are in red.

Activity Description & Estimated Class Time

Over two 50-minute class periods, students time the rate of a reaction (the dissolving of an antacid tablet) in different temperatures of water. They gather data and use it to generate a graph. They use the graph to predict either time or temperature when given the other variable.

Objectives

Students will demonstrate knowledge and understanding of the following ideas and content:

- Temperature affects the rate of a reaction.
- Control of variables is important in an experiment.
- Graphs of data can be used to predict results.

Students demonstrate this knowledge and understanding by agreeing on a procedure to determine the effect of temperature on the reaction of an effervescent tablet in water. They will use their collected data to generate a graph that can be used as a predictive tool.

Correlations to North Carolina Science Standards

8.P.1.3 Compare physical changes such as size, shape and state to chemical changes that are the result of a chemical reaction to include changes in temperature, color, formation of a gas or precipitate.

Correlations to Common Core State Standards for Mathematics

Statistics and Probability 8.SP Investigate patterns of association in bivariate data.

1. Construct and interpret scatter plots for bivariate measurement data to investigate patterns of association between two quantities. Describe patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association.
2. Know that straight lines are widely used to model relationships between two quantitative variables. For scatter plots that suggest a linear association, informally fit a straight line, and informally assess the model fit by judging the closeness of the data points to the line.

Brief Science Background

In general, most chemical reactions speed up as temperature rises. At higher temperatures, particles collide more often, and more molecules have enough energy for bonds to form or break. Students will observe how temperature affects the rate of reaction between the sodium bicarbonate and citric acid in an effervescent tablet. In water, these two compounds combine as follows:

sodium bicarbonate + citric acid → carbon dioxide + water + sodium citrate

$3\ NaHCO_3 + H_3C_6H_5O_7 \rightarrow 3\ CO_2 + 3\ H_2O + Na_3C_6H_5O_7$

The CO_2 gives the tablets their fizz, and the sodium bicarbonate helps to neutralize an overly acid stomach.

Part 1 — Reaction Rates (50-minutes)

Materials

Materials for the whole class

- 1 hot pot
- 1 gallon thermos bottle with hot water (60-70 ˚C)
- ice water (supplied by teacher)
- room temperature water (supplied by teacher)

Materials for tables of 4 (2 teams per table)

- 1 dump bucket (supplied by teacher)

Materials for groups of 2 students

- 1 thermometer
- 6 effervescent tablets
- 2 Styrofoam cups, 8 oz, for hot and cold water
- 1 plastic cup, 9 oz, for mixing
- 2 plastic cups, 3.5 oz, for running the trials
- 1 graduated cylinder, 50 ml
- 1 stopwatch

Preparation

1. Prepare hot water in the hot pot and transfer it to the thermos container for distributing to students.
2. Prepare some bottles of ice water.
3. Allow a water supply to sit at room temperature overnight.

Procedure

1. Ask students to fill a 3.5 oz cup with 50 ml of room temperature water. Tell them that they will drop an effervescent tablet in the water and time how long the reaction takes from beginning to end. Ask them to describe in their notebooks the conditions in the cup at the moment they declared the reaction "stopped." Students will get a wide range of results. Asking the class to agree on how they want every team to determine the endpoint can produce a very useful discussion. If they cannot agree, the easiest reaction endpoint to determine is when the tablet can no longer be seen. The tablet disappears before the bubbles stop, and it is easier to measure. Once an endpoint is agreed upon, the class can practice determining the endpoint together using room temperature water.
2. Tell students that they will investigate how temperature affects the speed of the chemical reaction in an effervescent tablet. Before the students begin, ask them what factors they need to consider so that different groups' results will be comparable. What factors could vary from experiment to experiment? What would everyone need to try to make the same? The discussion helps students think about controlling variables in an experiment. Make a list with the class from student input. The list should include:

Procedure Cont.

- The amount of water (try to get the class to agree on something near 50 ml).
- The temperature of the water (try to get the class to agree on four 10 ºC intervals—for example, 5, 15, 25, and 35 ºC).
- How beginning and end times of the reaction are determined.
- What the beginning and end of the reaction look like.

3. When students are ready to begin, distribute hot and cold water in Styrofoam cups. These may need to be refilled from time to time during the trials.
4. Students should mix hot and cold water in the 9 oz plastic cup, using the thermometer to get the correct temperature. They then measure 50 ml of this water with the graduated cylinder and pour it into a 3.5 oz reaction cup. Students should check the temperature of the water in the cup one final time before dropping in the tablet.
5. Tell students that for each trial, they will time the reaction from start to finish and record the data (time and temperature) in a table. Ask them to record any special observations they make in their notebooks.
6. Ask students to collect time data at four different temperatures. Stress that the temperatures should be different by at least 5 degrees C. A natural break in the activity is the point when students have collected all of their data.
7. Begin the next class period by asking students to describe their results. Ask how these results would look on a graph. Discuss how to set up a graph so that graphs from different teams can be compared. Tell the class to always put what they know before the experiment (temperature in this case) on the horizontal X-axis, and put what they find out (time in this case) on the vertical Y-axis.
8. Post all of the graphs and discuss them with the class. Ask about how the graph might be used. Ask about points between and beyond those that are on the graph (interpolate and extrapolate).
   - Have a cup of known temperature water and ask the class to use their graphs to predict how long it will take the tablet to dissolve. Do the test and compare the results with predictions.
   - Ask teams to set up a cup of known water temperature and record that temperature, then trade water with another team. Teams will run the reaction without measuring the starting temperature and use their graph to determine what the starting temperature must have been.

Wrap-Up

1. Discuss the accuracy of predictions made by the graphs. Ask students what could be done to make the graph predictions more accurate.
2. Ask students for their ideas on why an increase in temperature speeds up the reaction. Discuss the notion that higher temperature in a system indicates more energy in the system. Explain that the discovery that higher temperatures sped up reactions supports the idea that matter is made of small bits that can interact to produce chemical changes. The higher the temperature, the more often particles collide. In addition, the higher the temperature, the more molecules have enough energy to form or break bonds.

Guided Practice

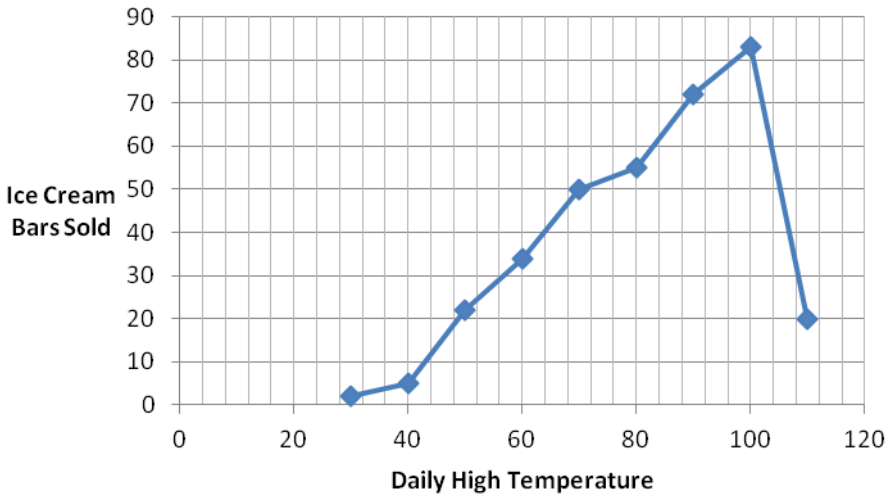
Guided Practices are similar to typical tests, but require students to reveal their thinking about content. They serve as a practice before a test and should not be graded. They are intended to expose misconceptions *before* an assessment and to provide opportunities for discussion, re-teaching, and for students to justify answers. They are best given as individual assignments without the manipulatives used in the activity. In that context, pose the following "test items" to the class. Ask them to write responses in notebooks.

This guided practice can be assigned in two different ways. Give raw data if students need practice making a graph. Give the pre-made graph of the same data if students need practice interpreting a graph. The analysis questions are the same in both cases.

Three students made a graph of the ice cream sales from their bicycle ice cream cart. They want to be better at ordering the right amount of ice cream bars based on the predicted temperature for the day. The data are presented below and the graph is on the next page.

1. What general trends are shown by the graph?
2. The predicted temperatures for a three day weekend are 75 degrees, 85 degrees and 95 degrees. About how many ice cream bars should the students order so they won't run out but not have too many extra?
3. Between what two temperatures do sales increase the most?
4. Between what two temperatures do sales decrease the most?

Daily High Temperature	# Ice Cream Bars Sold
30	2
40	4
50	22
60	34
70	51
80	55
90	72
100	83
110	20


Temperature and Ice Cream Bar Sales
Ice Cream Bars Sold
90
80
70
60
50
40
30
20
10
0
0
20
40
60
80
100
120
Daily High Temperature