Focused Learning Lesson
Physical Science
Grades 9 – 12
PS-H-D4

Overview:
This lesson offers a simulation and hands-on experience, which examines the effect of temperature on reaction rate.

Approximate Duration: 45 minutes

Benchmark:
PS-H-D4 analyzing the factors that affect the rate and equilibrium of a chemical reaction
PS GLE: 25. Determine the effect of various factors on reaction rate (e.g., temperature, surface area, concentration, agitation).
Benchmark:
S1-H-A7 utilizing science safety procedures during scientific investigations
SI GLE: 10. Given a description of an experiment, identify appropriate safety measures.

Objectives:
1. Identify temperature as a factor that affects the rate of a reaction.
2. Recognize how temperature can affect the rate of a reaction.
3. The learner will explain what is meant by reaction rate.
4. Determine whether the rate of a reaction is increasing, decreasing, or remaining constant.

Teacher Preparation: See *Teacher Background* found in Attachment 1.

Materials:
- baking soda *(sodium bicarbonate)*
- plastic teaspoon
- 250 mL beaker (*or other glass container to contain the chemical reaction)*
- vinegar *(acetic acid)* stored at room temperature
- vinegar *(acetic acid)* stored on ice
- 25 mL graduated cylinder *(or something that measures in ounces)*
- paper towels
- watch with a second hand

If possible, include vinegar kept warm on a hot plate or in a hot water bath.

Lesson Procedures:
Set Induction:
Ask for ten student volunteers. If the class is composed of less than ten students, have all the students participate; if the class is composed of ten to fourteen students, have all the students participate. Ask volunteers to stand next to each other in a group formation (clustered). Ask volunteers to pretend they are cold; i.e., have them huddle close together. Ask volunteers to pretend they are gradually getting warm and have them

slowly move apart. Ask volunteers to pretend they are suddenly very hot and have them pretend that they have absorbed more energy so that they move apart quickly. Repeat the exercise, but this time, do not tell the students how to move, just tell them what conditions are being simulated (cold, warm, hot). Have the students return to their seats.

Body of the Lesson:

1. Ask: "What was the meaning of the exercise?" *(Use probing questions if necessary; prior knowledge should have students commenting on the movement of particles under different temperature conditions.)* See Teacher Background.
2. Ask students if they think that the movement of particles affects whether or not and how chemicals will react with each other. Accept all reasonable responses. This question directs students' thoughts toward the concept of factors that affect reaction rate.
3. Provide students with a copy of Attachment 3, A Chemical Reaction, and ask students to identify appropriate safety considerations.
4. Implement the activity, A Chemical Reaction. For directions, see Attachment 2.

Closure:

Discuss answers to questions four, five, and six from the activity, A Chemical Reaction. See Teacher Background. After discussion, have students answer the two questions on the handout, Attachment 5, Rates of Reaction Assessment.

Attachments:

Attachment 1: Teacher Background
Attachment 2: A Chemical Reaction
Attachment 3: A Chemical Reaction (Student Copy)
Attachment 4: A Chemical Reaction: Key
Attachment 5: Rates of Reaction Assessment
Attachment 6: Rates of Reaction Assessment: Key

Assessment:

Teacher observation is used for formative assessment. Questions 1-6 on the activity, A Chemical Reaction, should be evaluated for completeness and to check for level of student understanding. The assessment, Rates of Reaction, should be evaluated for completeness and to check for level of student understanding.

Reference and Links:

Cohen, P.S., Deutsch, J. & Sorrentino, A.V. (2003). *Reviewing Science* (p 225).

Information on factors that affect reaction rate:
http://www.chem4kids.com/files/react_rates.html

More advanced information on factors that affect reaction rate:
http://www.gcsechemistry.com/xrc.htm

Attachment 1
Teacher Background

Concepts:

Reaction Rate: The ***rate of a reaction*** is how fast (or slow) the reaction occurs. Reaction rates can be determined by measuring the amount of product that is produced over a period of time.

The Effect of Temperature on Reaction Rate: For the set induction activity, students should understand that as particles are heated they move faster and further apart. Reactions occur as particles of different substances come in contact with each other. If the particles of a certain substance stay in one place, then they are less likely to come into contact (or will take longer to come into contact) with another substance and are less likely to react.

Chemical Reaction

The chemical reaction taking place in the activity is as follows:

$$NaHCO_3 + HC_2H_3O_2 \longrightarrow NaC_2H_3O_2 + CO_2 + H_2O$$

$NaHCO_3$ *(sodium bicarbonate or baking soda)* and $HC_2H_3O_2$ *(acetic acid or vinegar)* are reactants. A ***reactant*** is a substance that is a starting material before a chemical reaction.

$NaC_2H_3O_2$ *(sodium acetate),* CO_2 *(carbon dioxide),* and H_2O *(water)* are products. A ***product*** is a substance that is formed as a result of a chemical reaction.

The vinegar is the substance that is the key to how fast the reaction will occur in this activity. Colder vinegar particles will not move apart from each other as fast as warmer vinegar particles. Therefore, warmer vinegar particles make contact with particles of the baking soda quicker, causing a more rapidly progressing reaction.

Factors Affecting Rate of Reaction:

There are four factors which can affect the rate of a chemical reaction: temperature, agitation, concentration, and surface area.

- ***Agitation***, which usually takes place by stirring, causes particles to come into contact with each other more readily, which increases the rate of reaction.
- When a substance is used that has a high ***concentration***, the substance has more particles available to come into contact with the particles of another substance than if it would have at a low concentration; therefore, higher concentrations increases the rate of reaction.
- ***Surface area*** refers to the amount of exposed surface available to come into contact with another substance. A cube of sugar which has been crushed (powdered) has a larger surface area overall than does a cube of sugar which is still whole. The larger surface area of the smaller pieces affords greater opportunities for coming into contact with the particles of another substance, thereby increasing the rate of reaction.

Attachment 2
A Chemical Reaction

Prepare a lab station with the following items:

- baking soda *(sodium bicarbonate)*
- plastic teaspoon *(to measure the sodium bicarbonate)*
- 250 mL beaker (*sealable quart baggie, plastic drink glass or any other glass container to hold the chemical reaction)*
- vinegar *(acetic acid)* stored at room temperature
- vinegar *(acetic acid)* stored on ice
- 25 mL graduated cylinder *(or something that measures in ounces)*
- paper towels *(to absorb spills)*

If possible, also include vinegar (acetic acid) kept warm on a hot plate or in a hot water bath.

Divide the class into cooperative pairs of students or groups of three. Give each pair one copy of the handout: A Chemical Reaction Student Copy, Attachment 3. Have the students read over the directions before proceeding with the experiment.

Safety concerns:

- Students should be advised against putting anything in their mouths.
- Students should wash hands after the experiment.
- If the vinegar, baking soda, or products of the reaction come into contact with the eyes of a student, the student should flush his eyes thoroughly.
- Spills can be wiped up with a paper towel and discarded in the trashcan.

Problems with the procedure:

- If the reaction does not occur (fizzing should take place), then more than likely the baking soda is old. There is a possibility that the vinegar could be old.
- If students do not see a difference between the reactions with the vinegar at different temperatures, then have them repeat the experiment keeping in mind that they must focus on this concept.

Attachment 3
A Chemical Reaction: Student Copy

Directions: Read the entire handout before preceding any further. The teacher has set up the materials for this activity. Below is the procedure for the activity.

1. Add approximately 10 mL (two teaspoons) of baking soda *(sodium bicarbonate)* to the beaker or other container.
2. Place the container with the baking soda in the center of the lab table or desk. Have paper towels handy in case of overflow.
3. Add 15 mL *(1T. or 0.5 ounces)* cold vinegar *(acetic acid)* to the beaker all at once. If a baggie is used, seal the baggie.
4. Record the name of the substances combined and what you observed in the data table provided. Time the reaction from the time the ingredients were combined until they stopped reacting *(reaction rate)* using a watch with a second and then record the time.
5. Wash out the contents of the beaker or dispose of the baggie. Dry the beaker with a paper towel.
6. Repeat steps one and two.
7. Add 15 mL *(0.5 ounces)* room temperature vinegar *(acetic acid)* to the beaker all at once. If using a baggie, seal the bag.
8. Record substances combined and your observations in the data table provided. Note the speed *(reaction rate)* of the reaction. Specifically, compare the speed of this reaction to the speed of the reaction with the cold vinegar.
9. Wash out the contents of the beaker or discard the baggie. Dry the beaker with a paper towel.

Continue with steps 10 - 13 only if warm vinegar (acetic acid) is available.

10. Repeat steps one and two.
11. Add 15 mL *(1T. or 0.5 ounces)* warm vinegar to the container all at once. If a baggie is used, seal it quickly.
12. Record the name of the substances combined and what you observe in the data table provided. Use a watch with a second hand to time the reaction. Note the speed *(reaction rate)* of the reaction. Specifically, compare the speed of this reaction to the speed of the reaction with the room temperature vinegar *(acetic acid).*

Data Table 1: Chemical Reactions

What was Combined	What was Observed	**Reaction Time** *in seconds*

Questions

Answer the questions on a separate sheet of paper. Be sure to number your answers.

The same reactions occurred for all three *(or two, if warm vinegar was not used)* trials.

baking soda + vinegar ⟶ sodium acetate + carbon dioxide + water

sodium bicarbonate + acetic acid ⟶ sodium acetate + carbon dioxide + water

The same reactants were combined. The same products were produced.

1. If the same reaction occurred in each situation, then what was the difference for each situation?

2. What caused this difference?

3. At the beginning of class, students were placed in a group and asked to pretend that they were cold, then warm, then hot. They reacted differently if they were cold, warm, or hot. Compare the way the students reacted for the three different temperatures to the way the baking soda combined with the vinegar reacted for the three different temperatures. How did they react alike? How did they react differently? *(If warm vinegar was not used, then just compare to the cold vinegar and the room temperature vinegar.)*

There are three other factors that may affect how fast a reaction occurs. These factors include agitation (stirring), surface area (small pieces vs. one large piece), and concentration (the vinegar is a weak solution of acetic acid. A stronger solution would have more molecules of acetic acid per unit of water). With this information in mind, do your best to answer the following questions.

4. Why would stirring or shaking affect the reaction rate?

5. Why would differences in surface area affect the reaction rate?

6. Why would concentration of a reactant affect the reaction rate?

Attachment 4
A Chemical Reaction: Key

Data Table 1: Chemical Reactions

What was Combined	What was Observed	Reaction Time *in seconds*
cold vinegar + baking soda	*fizzing, bubbles, or gas formation* *It happened fast. Students should record the number of seconds from the beginning of reaction to the end of the reaction.*	*response varies*
room temperature vinegar + baking soda	*fizzing, bubbles, or gas formation* *It happened faster than with cold vinegar. Students should record the number of seconds from the beginning of reaction to the end of the reaction.*	*response varies*
warm vinegar + baking soda	*fizzing, bubbles, or gas formation* *It happened even faster than with room temperature vinegar. Students should record the number of seconds from the beginning of reaction to the end of the reaction.*	*response varies*

Questions: *(answer the questions on a separate sheet of paper)*

The same reaction occurred for all three *(or two, if warm vinegar was not used)* trials. The same reactants were combined. The same products were produced.

1. If the same reaction occurred in each situation, then what was the difference for each situation?
   The temperature of the vinegar was different.

2. What caused this difference?
   The warmer the temperature, the faster and further apart the vinegar particles moved. As the vinegar particles moved faster and further apart, they came into contact with the baking soda particles more readily causing the rate of reaction to increase.

3. At the beginning of class, students were placed in a group and asked to pretend that they were cold, then warm, then hot. They reacted differently if they were cold, warm, or hot. Compare the way the students reacted for the three different temperatures to the way the baking soda combined with the vinegar reacted for the three different temperatures. How did they react alike? How did they react differently? *(If warm vinegar was not used, then just compare to the cold vinegar and the room temperature vinegar.)*
   Student answers should include information such as:
   The students moved apart as they became "warmer."
   The vinegar particles moved faster and away from each other as they became warmer.

The vinegar particles collided with and reacted with the baking soda.
The students did not react with anything.

There are three other factors that may affect how fast a reaction occurs. These factors include agitation (stirring), surface area (small pieces vs. one large piece), and concentration (the vinegar is a weak solution of acetic acid - it has so many particles of acetic acid per unit of water – a stronger solution would have more particles of acetic acid per unit of water). With this information in mind, do your best to answer the following questions.

4. Why would stirring affect the reaction rate?
   Stirring causes the particles to come into contact with other particles quicker.

5. Why would surface area affect the reaction rate?
   The greater the surface area, the more particles there are that are easily available to take part in a reaction.

6. Why would concentration affect the reaction rate?
   The higher the concentration, the more particles there are available to take part in a reaction.

See Teacher Background for additional information that students might include in their responses.

Attachment 5
Rates of Reaction Assessment

___ 1. Hydrogen gas is produced in a chemical reaction between zinc and an acid. Which setup would most likely have the fastest reaction rates?

a. Zinc strip at 20^{o}C
b. Powdered zinc at 20^{o}C
c. Zinc strip at 30^{o}C
d. Powdered zinc at 30^{o}C

Explain why you think that your answer is correct below.

___ 2. Which sample of wood would most likely burn the fastest?

a. Log
b. Planks of wood
c. Toothpicks
d. Sawdust

Explain why you think that your answer is correct below.

Attachment 6
Rates of Reaction Assessment: Key

1. Hydrogen gas is produced in a chemical reaction between zinc and an acid. Which setup would most likely have the fastest reaction rates?
   a. Zinc strip at 20°C
   b. Powdered zinc at 20°C
   c. Zinc strip at 30°C
   d. Powdered zinc at 30°C

   Explain your answer.

   d. *Because both larger surface area (powdered) and higher temperature (30°C as opposed to 20°C) will increase the reaction rate.*

2. Which sample of wood would most likely burn the fastest?
   a. Log
   b. Planks of wood
   c. Toothpicks
   d. Sawdust

   Explain your answer.

   d. *The larger amount of surface area in sawdust would increase the reaction rate. More surface is exposed to oxyen.*

Cohen, P.S., Deutsch, J. & Sorrentino, A.V. (2003). *Reviewing Science* (p 225).