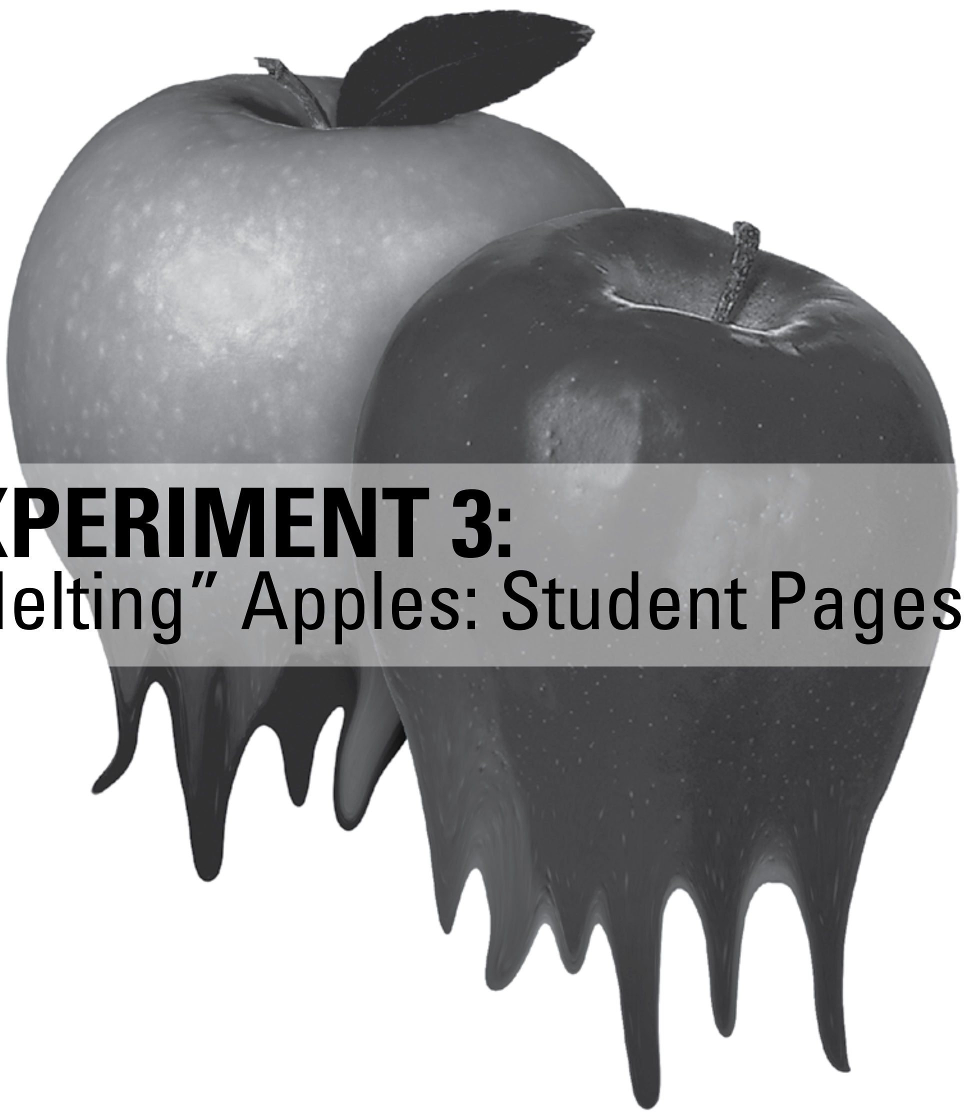


# EXPERIMENT 3:
## "Melting" Apples: Student Pages

### USING A TEMPERATURE GRAPH TO SHOW PHASE CHANGES IN APPLESAUCE

### BACKGROUND

Have you heard the old saying "An apple a day keeps the doctor away?" Apples are popular fruit that have been cultivated in North America for several centuries, beginning with the Native Americans. These early trees produced "crab apples," which are a small, hard, sour fruit. The English colonists brought over other varieties of apples, along with honeybees for pollination purposes. The apple trees spread west with settlers, thanks in part to John Chapman. Known more widely as "Johnny Appleseed," Chapman distributed apple seeds from cider mills to settlers who were headed west. Apples continue to be a popular fruit today among farmers and consumers, with the average American eating 18 pounds of fresh apples a year.

Apples, scientifically named *Malus domestica*, are one of the most popular fruits sold in the world today. They are used to make everything from apple juice to apple pie. One of the reasons they are so widely used is because of their high water content. Apples are made up of 85% water and 10% sugar. With all that water, it gives us as scientists the opportunity to test how temperature and time can be used to create a “sauce” or liquid version of apples.

Matter appears in many phases including solids and liquids. The difference in phases is due to different amounts of energy and the arrangement of molecules and atoms (see Figure 3.1). Solids have atoms that are tightly bound and vibrate because of their packed nature and lower energy. Liquids have atoms that can move freely around each other and have a higher energy state when compared with atoms in solids.

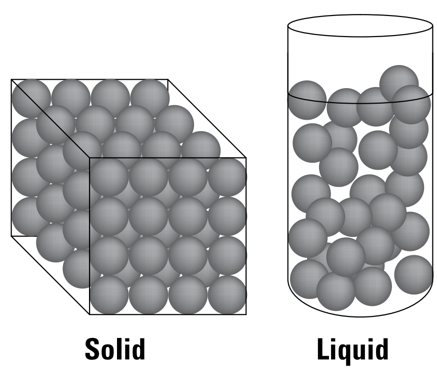



**Figure 3.1: Molecule arrangements for a solid and a liquid.**

In this experiment we will look at how much energy is required to change a solid apple to liquid applesauce to create a delicious final product.

## HYPOTHESIS

Based on your knowledge of heat and water, what temperature will the apples “melt” at? In other words, when will the apples change from a solid to a liquid? Make a hypothesis stating an exact temperature the apples will change from liquid to solid, with an explanation of why you think that change will occur.

## MATERIALS NEEDED PER GROUP

- Two *Malus domestica* (apples) halved and cored
- 90 ml of dihydrogen monoxide, $H_2O$ (water)
- 30 ml of sucrose, $C_{12}H_{22}O_{11}$ (sugar)

- Beaker, 400 ml
- Tongs
- Glass stir rod
- Bunsen burner and ring stand, or hot plate
- Plastic knives, one for each student
- Plastic or metal fork
- Metal scoop
- Paper towels
- Paper cups, one per student
- Graduated cylinder, 100 ml
- Thermometer (nonmercury)
- Clock/timer
- Indirectly vented chemical-splash goggles
- Aprons

## PROCEDURE

1. Read through the entire Procedure section before beginning.
2. Put on your safety goggles and apron, and gather all your materials at your lab station. If you notice any of the materials are dirty or discolored, notify your teacher.
3. Begin by washing your *Malus domestica* in the sink with cold water, cleaning off any excess dirt.
4. Place the *Malus domestica* on a dry paper towel, and begin the process of removing the outer layer of skin. This can be achieved using the plastic knife or metal scoop. Push down gently on the *Malus domestica* with your chosen tool and scrape off the skin. Make sure you are scraping away from your body and all appendages (such as other fingers).
5. Discard the skin. Using the same paper towel, begin the process of chopping your *Malus domestica* into small pieces. The pieces should be no larger than the size of a dime, about 2 cm × 2 cm.
6. Place all the *Malus domestica* pieces into a 400 ml beaker.
7. Measure 30 ml of sucrose into a graduated cylinder and add it to the 400 ml beaker with *Malus domestica*.
8. Measure 90 ml of $H_2O$ in a graduated cylinder and add it to the 400 ml beaker with the *Malus domestica* and sucrose.
9. Set up a Bunsen burner and ring stand with wire mesh on the iron ring. Make

sure your Bunsen burner gas intake tube is securely connected to the gas nozzle, and that the ring is set about 3 in. above the barrel of the burner (see Figure 3.2). Light the Bunsen burner to create a flame that is no more than 3 in. high. (It should not be touching the wire mesh.)

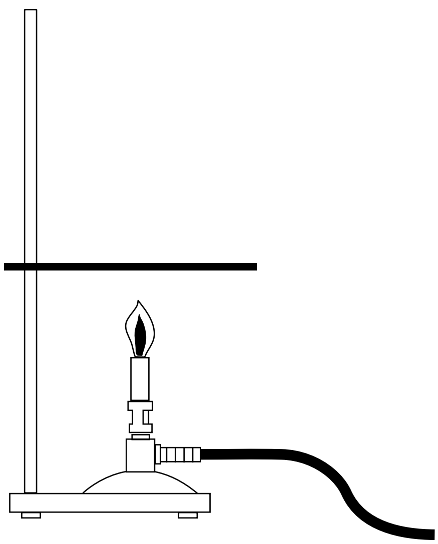


**Figure 3.2: Bunsen burner and ring stand.**

10. Using the tongs, place the beaker onto the ring stand. Note the time that you begin heating.
11. Slowly stir the mixture in the beaker. Make sure you stir with a glass stir rod and not the thermometer or plastic knife. This keeps the mixture heating evenly so nothing burns.
12. After one minute, measure the amount of thermal energy present within the molecules in the beaker. Carefully place the thermometer in the mixture and record the temperature in degrees Celsius in your Energy Data Table. Repeat this step every minute until 20 minutes have passed.
13. After 20 minutes, use the tongs to remove the beaker from the heat and allow it to cool for three minutes. You can begin to clean your lab station during this time.
14. After three minutes, mash the remaining *Malus domestica* with a fork.
15. Pour the liquid into paper cups for the group and feel free to eat your final lab product.

16. Clean your lab table and answer the Data Analysis and Conclusion and Connections questions.

## DATA AND OBSERVATIONS

| Energy Data Table | | |
|---|---|---|
| Time (minutes) | Temperature (Celsius) | Observations (sight and smell) |
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |
| 11 | | |
| 12 | | |
| 13 | | |
| 14 | | |
| 15 | | |
| 16 | | |
| 17 | | |
| 18 | | |
| 19 | | |
| 20 | | |

## DATA ANALYSIS

For each of the following questions, be sure to explain using detail and complete sentences. If the question requires you to complete calculations, show all of your work.

1. Draw a line graph of your temperature data obtained while heating the apple pieces. Remember to include all elements of a scientific graph (title, labeled axes, units, etc.).

2. What is the total amount of energy that you gained in the *Malus domestica* mixture from the start of the experiment until the end?

3. What was the average energy gain per minute for the *Malus domestica* mixture over the course of this experiment?

## CONCLUSION AND CONNECTIONS

1. In the table below give three characteristics of a solid and three characteristics of a liquid.

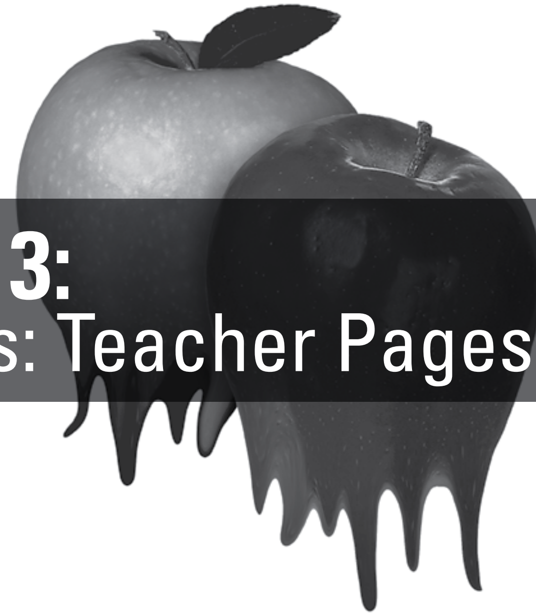
| Solid | Liquid |
|---|---|
| 1. | 1. |
| 2. | 2. |
| 3. | 3. |

2. As the *Malus domestica* mixture gained energy, it turned into a liquid. Explain why atoms with more energy would be a liquid rather than a solid. Feel free to use pictures or diagrams to explain your answer.

3. During one point in the experiment the thermal energy of the mixture did not increase or decrease. (There is a horizontal line on your graph that shows the energy was not changing.) Why did the energy stay the same if you were continuing to add heat?

4. Why do you think it is necessary to remove the skin or peel from the *Malus domestica* before heating it?

5. Sketch what you predict your graph would look like if you did not remove this part of the apple before heating. Label the axes on your graph.



# EXPERIMENT 3:
# "Melting" Apples: Teacher Pages

## USING A TEMPERATURE GRAPH TO SHOW PHASE CHANGES IN APPLESAUCE

This experiment allows students to study a phase change in a way that is accessible and edible. The experiment models a physical change from solid to liquid through the release of sugars and water from the apples. Building on the ideas of physical and chemical changes introduced in Experiment 1: Butter Battle, students measure the amount of thermal energy that occurs during a phase change and link that change back to atomic structure and phases of matter. This experiment is a great alternative to melting an ice cube into water, and gets students asking questions about how temperature and energy relate to states of matter. The content is reinforced through graphing and math equations to provide a lab that integrates data analysis skills and scientific knowledge.

## STANDARDS ADDRESSED

**National Science Education Standards: Grades 5–8**

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Properties and changes of properties in matter
- Transfer of energy

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in society

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of science

**National Science Education Standards: Grades 9–12**

Content Standard A: Science as Inquiry
- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science
- Structure of atoms
- Structure and properties of matter
- Interactions of energy and matter

Content Standard E: Science and Technology
- Abilities of technological design
- Understanding about science and technology

Content Standard F: Science in Personal and Social Perspectives
- Science and technology in local, national, and global challenges

Content Standard G: History and Nature of Science
- Science as a human endeavor
- Nature of scientific knowledge
- Historical perspectives

## VOCABULARY

**States of matter:** One of the four principal conditions in which *matter* exists: solid, liquid, gas, and plasma (The American Heritage Science Dictionary 2005).

**Solid:** A substance having a definite shape and volume; one that is neither liquid nor gaseous. A substance where the atomic molecules are closely packed together and vibrate (*The American Heritage Science Dictionary* 2005).

**Liquid:** One of four main states of matter, composed of molecules that can move about in a substance but are bound loosely together by intermolecular forces. Unlike a solid, a liquid has no fixed shape, but instead has a characteristic readiness to flow and therefore takes on the shape of any container. Because pressure transmitted at one point is passed on to other points, a liquid usually has a volume that remains constant or changes only slightly under pressure, unlike a gas (*The American Heritage Science Dictionary* 2005).

**Energy:** The capacity or power to do work, such as the capacity to move an object (of a given mass) by the application of force. Energy can exist in a variety of forms, such as electrical, mechanical, chemical, thermal, or nuclear, and can be transformed from one form to another. It is measured by the amount of work done, usually in joules or watts (*The American Heritage Science Dictionary* 2005).

**Heat:** Internal energy that is transferred to a physical system from outside the system because of a difference in temperature and does not result in work done by the system on its surroundings. Absorption of energy by a system as heat takes the form of increased kinetic energy of its molecules, thus resulting in an increase in temperature of the system. Heat is transferred from one system to another in the direction of higher to lower temperature (*The American Heritage Science Dictionary* 2005).

## MATERIALS NEEDED, DECODED FOR THE GROCERY STORE

Two *Malus domestica* (apples) halved and cored

- You will need two apples for each lab group to complete the experiment. Multiply the number of lab groups you have by two, and that will give you the quantity of apples necessary. It is often more cost-effective to purchase the apples that are already bagged in quantities of 10 or more rather than purchasing apples individually and paying by total weight.
- The variety of apples you choose is up to you. It's best to choose softer apples, so McIntosh or Red Delicious are good options. It's not recommended that you use Granny Smith apples, as they can be tart in the final applesauce, unless that is the taste you are trying to achieve.

90 ml of dihydrogen monoxide, $H_2O$ (water)

- This will be about a liter of water for every 10 student groups. If you have access to a sink or drinking fountain, this is a material you can get at school.

30 ml of sucrose, $C_{12}H_{22}O_{11}$ (sugar)

- Sugar is sold in 5 lb. bags. This will give you enough sugar for about 70 lab groups for this experiment.

Plastic knife

- I recommend having enough knives for each student in the group to have one. This helps speed up the peeling procedure for the apples and keeps all students involved. The knives can be cleaned and used for the next class, so buy as many as you'll need for your largest single class, plus a few extras in case there is breakage. Plastic knives are sold individually in boxes of 30–50.

Plastic or metal fork

- Plastic forks are ideal because they give students a device for mashing the apples and a device for eating the applesauce. If you are letting students use them only as a tool, they can be used as a class set. If you are allowing students to eat off of them as well, they can either be disposed of, or washed with dish soap before being used by another student. Purchase according to the size of your class and student groups.

Paper towel

- Each student group will need one paper towel to use while peeling and dicing their apples. This step makes it easier for students to keep all their apple pieces on the table. I encourage students to use the same sheet of paper towel for both peeling and dicing, keeping in mind that some paper towels will rip and need to be replaced. A single roll of paper towels will meet the needs of more than 100 students.

Paper cups

- The cups are used for dividing the final product of applesauce. Having enough cups for each student to have his or her own allows for the final amount to be divided equally, and students can drink the applesauce without using additional utensils. Paper cups are sold in packages of 200 to 1,000 depending on your needs.

Dish soap

- This is necessary for cleanup. I ask students to use an amount about the size of a quarter for each glass container, and I have one bottle available for every four lab groups to share.

## SAFETY HIGHLIGHTS

- Unless students are using plastic knives and forks that are disposable, it is necessary to sterilize the metal utensils before allowing them to be used in the experiment.
- The Bunsen burners and ring stands present a potential for students to burn themselves if used incorrectly. Please make sure students have had Bunsen burner safety training before allowing them to participate in this lab. As a teacher, you also need to be prepared with burn treatment options, such as running the burned area under cold water, if a student gets hurt.
- If a glass stir rod breaks, you should dispose of the entire mixture in the beaker. Even if the break is minor, you may have shards of glass in the mixture that are not visible.

Note that these safety highlights are in addition to the safety information detailed in the Safety Protocol section at the beginning of this book. Please refer to that section for additional information about safety when implementing this or any lab in this book.

## PREPARATION

1. Using a sharp metal knife, cut all the apples in half. I highly recommend cutting and coring the apples before giving them to students. The plastic knives are not sharp enough for students to adequately cut through the apple and remove the core, so this step needs to be completed prior to the lab.

2. If you are feeling particularly helpful, you can also peel the apples for the students ahead of time. This is a good idea if you have younger students and there are concerns about them handling a knife or sharp object. There are also apple-peeling devices that can be purchased for the students to use that reduces the safety risks of them removing the peel themselves. Most students enjoy removing the peel.

3. I recommend placing the paper towels at each lab station prior to the start of the lab. Many students tend to take too many, so if they have a set quantity to work with, this step can cut down on waste.



## PROCEDURE

I recommend having the students work in a pairs or groups of three for this experiment. Because of the peeling of the apples, as well as the constant temperature taking, timing, and stirring required in this experiment, there are enough tasks to keep two or three students focused and engaged throughout the experiment.

1. Begin by reading the Background section. Ask students to name their favorite foods that include apples, or why they think, “An apple a day keeps the doctor away,” as making that connection will help them become more invested in the lab.
2. The Background section introduces the idea of phases of matter. Ask students to brainstorm qualities or characteristics that distinguish a solid and liquid and write them on the whiteboard. Set out markers and ask each student to write at least one characteristic or quality that defines a substance as a solid or a liquid. I ask that each student contributes at least one idea to one of the two phases, and give them a few minutes to offer their answers. Another approach would be to assign individual student groups a specific phase, such as solids, and ask them to come up with a list of qualities that define a solid. Once the class is finished adding information, ask students to take a moment to look at the ideas and see if there is anything that they want to add, because reading the ideas often helps spark more ideas and thoughts.

| Characteristics of Solids | Characteristics of Liquids |
|---|---|
| 1. Definite shape<br>2. Definite volume<br>3. The atomic particles are packed closely together.<br>4. The atomic particles vibrate.<br>5. Not easily compressed, little free space between the particles | 1. Changes to fit the shape of the container<br>2. The atomic particles are able to move around each other, and have more energy than particles in a solid.<br>3. Not easily compressed, little free space between the particles |

3. Once students have an idea of the characteristics of each phase, you can ask how energy plays a role in each of these phases. I often show a rock and a glass of water and ask, “Which do you think has more energy? Why?” This allows students the opportunity to look at how objects in different phases have different amounts of energy in their molecules.

4. A great demonstration is to hold an ice cube in your hand. You can also ask a couple of student volunteers to do this as well, or give one to each lab group. Ask, "What phase is the ice cube in? As it sits in your hand, what phase is it changing to? Why does the ice cube make that change?" Most students are familiar with the melting of ice and will be able to say it is melting because it is heating up from the heat from your hand. Ask them how this relates back to changing energy.

5. This leads students to their hypothesis. Ask, "At what point will the energy be great enough to change apples from a solid to a liquid?" This is a great opportunity to let students talk it out within their lab groups. You can ask each student to make his or her own hypothesis, or ask the group to come up with a consensus verbally before writing anything. Circulate among the groups to see who understands the link between phase change and heat energy, and who is still unclear. When students try to describe why they believe this, I often remind students of the background information that states the apple is 85% water. Ask students what they know about water that would help them make a good hypothesis.

6. While students are cutting, you can ask each group, "Why is it necessary to cut the apple pieces so small?" The answer is to increase the surface area to improve energy transfer, which encourages the students to be thoughtful about their cutting.

7. The lab process takes about 10 minutes for students to peel, and another 20 minutes for the apples to heat and liquefy. Students can use the clock on the wall or timers to keep track of time and take data at the appropriate moments.

8. Students can use Bunsen burners or hot plates to achieve this phase change. If you have younger students, I recommend hot plates on medium heat. The older students may use the Bunsen burners, but depending on the size of your group, hot plates may be the safer choice.

9. Students are asked to measure out the sugar first. This is to prevent the sugar from sticking to the inside of the graduated cylinders. Make sure students obtain the sugar first in dry cylinders to prevent a sticky mess.

10. Remind students to continually stir their mixture. If the heat is too high, the apples and sugar can burn, which makes it nearly impossible to clean the beaker. Many students will want to stir with the thermometer. This is not a good idea because they are designed as measuring tools, not for the utility of stirring. If there are three students, I often ask them to take on the following roles:

- Timekeeper—This person is in charge of watching the timer or the clock on the wall and letting his or her group know when to take temperature readings.
- Energy monitor—This person is in charge of measuring the temperature and recording the data in the data table.
- Chef—This person is in charge of monitoring and stirring the mixture consistently throughout the experiment.

These roles help students use the tools appropriately and stay engaged in the entire lab.

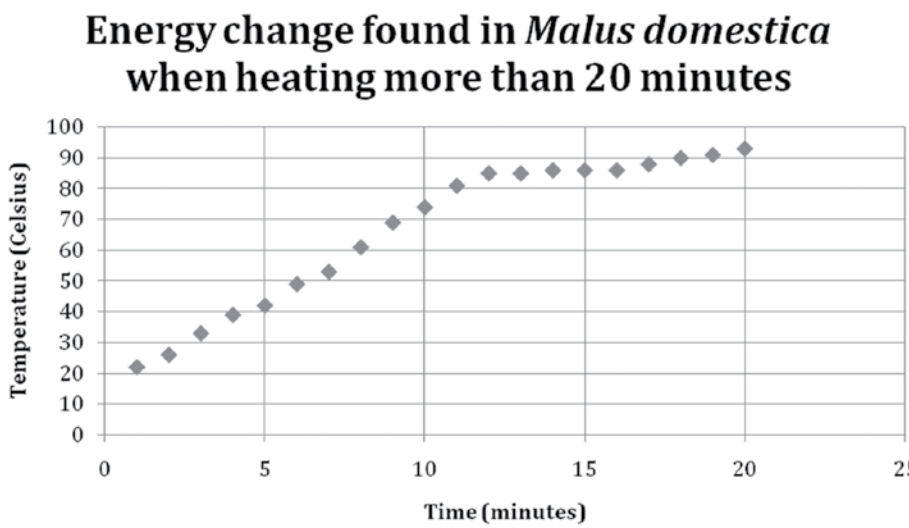
11. Soap is necessary to clean all the equipment thoroughly after this lab.

## DATA ANALYSIS ANSWER KEY

All the data analyses for this lab are math based. If students are struggling with the calculations, I recommend using a sample data set and going through the calculations as a class on the board. Then they can use the same skills and apply them directly to their data.

1. ***Draw a line graph of your temperature data obtained while heating the apple pieces. Remember to include all elements of a scientific graph (title, labeled axes, units, etc.).***

   Each student's graph will be slightly different based on actual temperatures achieved in the experiments. This is a great opportunity for students to use the graphing standards of their math classes. An example student graph is on page 55:




2. ***What is the total amount of energy that you gained in the* Malus domestica *mixture from the start of the experiment until the end?***

   Answers to this question will range based on the students' individual data but should be fairly consistent based on the initial room temperature for all students and the final heating temperature of the apple mixture. Students can solve for the answer by taking their final temperature reading and subtracting their initial temperature reading. A sample student calculation could look like this:

   | | | | | |
   |---|---|---|---|---|
   | 91°C<br>Final temperature reading | – | 22°C<br>Initial temperature reading | = | 69°C |

3. ***What was the average energy gain per minute for the* Malus domestica *mixture over the course of this experiment?***

   Again, individual student data will vary slightly based on their methods and specific data. Students can solve this problem by taking the total temperature change (their answer to Data Analysis question 2) and dividing it by the 20-minute time over which the mixture was heated. A sample student calculation could look like this:

   69°C total temperature change ÷ 20 minutes = 3.45°C change per minute

## CONCLUSION AND CONNECTIONS ANSWER KEY

This section of the lab offers a great opportunity to engage the entire class in discussion to clarify the main ideas of the lab and allow students to make their own connections between science and cooking. I ask that students complete the Data Analysis questions and attempt to answer the Conclusion and Connections questions with the understanding that we will spend time the next day discussing the Conclusion and Connections section.

1. ***In the table below give three characteristics of a solid and three characteristics of a liquid.***

   For this answer, students should be able to use the brainstorm from the board in their answer. If students did not start with characteristics and provide only examples, this is a good moment to discuss what characteristics are shared by all the items and put together a class list.

| Solid | Liquid |
|---|---|
| 1. Definite shape<br>2. Definite volume<br>3. The atomic particles are packed closely together.<br>4. The atomic particles vibrate.<br>5. Not easily compressed, little free space between the particles | 1. Changes to fit the shape of the container<br>2. The atomic particles are able to move around each other, and have more energy than particles in a solid.<br>3. Not easily compressed, little free space between the particles |

2. ***As the* Malus domestica *mixture gained energy, it turned into a liquid. Explain why atoms with more energy would be a liquid rather than a solid. Feel free to use pictures or diagrams to explain your answer.***

   Atoms with more energy are going to be more likely to move around each other, and that movement is seen in liquids, which change their shape to fit their container. It is often helpful to have students draw a picture of the molecules in a solid and liquid to explain the difference. Use the applesauce example to explain how the atoms were gaining energy from the flame and are to change into a liquid.

3. ***During one point in the experiment the thermal energy of the mixture did not increase or decrease. (There is a horizontal line on your graph that shows the energy was not changing.) Why did the energy stay the same if you were continuing to add heat?***

   This occurs when the mixture contains both solids and liquids. The temperature remains constant because it is trying to excite all the atoms to a state in which they can all be liquid. The energy is being directed at getting all atoms throughout the mixture to the same temperature, which keeps the temperature constant.

4. ***Why do you think it is necessary to remove the skin or peel from the Malus domestica before heating it?***

   The skin or peel of the apple works as human skin does: to help keep moisture in. Placing a whole unpeeled apple on the table next to an apple that has been peeled can clearly show this to students. The whole apple will retain its moisture, while the apple without a skin slowly begins to dry up. Many students have seen this and can be led to this answer by asking them what happens to sliced apples when they are left out on the table for a long time. If the skin was left on during heating, it prevents the loss of water, making it more difficult to heat the apples in the time provided. The applesauce would remain chunky and uneven because of the skin preventing water from escaping from the fruit.

5. ***Sketch what you predict your graph would look like if you did not remove this part of the apple before heating. Label the axes on your graph.***

   Students generally take one of two approaches to this question. Some may think that because the apple is being prevented from losing water, it may take more heat and therefore have a higher final boiling temperature. On the other hand, students might assume that it takes longer for the heat to achieve a fully liquid phase and therefore have a line that shows a longer time where the temperature does not change. Either answer shows that students are thinking about how the peel impacts energy and phase changes in apples, so both are acceptable for this conclusion.



## CROSS-CURRICULAR NOTE: TECHNOLOGY

This is an ideal opportunity to use technology in the classroom by asking the students to create their graphs on computers using software such as Microsoft Excel.

## CROSS-CURRICULAR NOTE: MATH

This is an ideal opportunity for students to work with a direct application of solving for averages and rates.

## CROSS-CURRICULAR NOTE: LITERACY

Johnny Appleseed is a historical figure that is highlighted in many poems and songs. Have students research a poem about Johnny Appleseed, or give them one as a class. Ask students to write their own haiku (a three-line poem with five syllables in the first line, seven syllables in the second line, and five syllables in the third line) about their favorite fruit.

## OPTIONAL EXTENSIONS

**Middle School**

1. Another option for increasing the complexity of the lab is to allow students to choose different varieties of apples, or vary the size of the apple pieces to see if it affects the temperature required for the apples to change phase. Students can pool data from several groups and graph all the data sets on a single plot to compare.

2. To use this lab with more student inquiry, encourage students to develop their own recipe for making applesauce. Use the demonstration with the ice cube melting to prompt them to consider how to "melt" an apple into sauce. Allow them to create the materials list and procedure, and make changes and adjustments based on the quality of the final applesauce.

3. Encourage students to test what would happen to the temperature required for the melting of the apples when the peel is left on. Relate the impact on temperature to the roll of the peel to maintain moisture within the fruit.

**High School**

1. Students can consider how the percentage of water content affects the melting temperature of different fruits. Allow students to bring in their own fruits, make predictions about melting points based on water content, and test the creation of peach sauce, banana sauce, and so on.

2. Have students investigate the chemical makeup of an apple and how the arrangement of molecules affects the temperature that allows it to move from a liquid to a solid. Students can test different materials, such as chocolate and butter, to compare the temperature at which the phase transition from solid to liquid occurs. Challenge students to predict the melting temperature of an object based on its chemical structure.