*Lab Handout*

# Lab 17. Rate of Energy Transfer

## How Does the Surface Area of a Substance Affect the Rate at Which Thermal Energy Is Transferred From One Substance to Another?

### Introduction

Understanding how energy is transferred from one object or substance to another is an important concept within science. Many common events involve a transfer of energy, such as heating a pot of water on the stove or when a car engine burns gasoline. In the first example, heat energy is transferred from the stove to the pot of water, and the water absorbs the heat energy and will eventually begin to boil. In a car, the chemical energy stored in the gasoline is released when it is burned in the engine; that chemical energy is ultimately converted to kinetic energy and results in the motion of the car.

The law of conservation of energy indicates that energy is not created or destroyed, only converted from one form to another. There are many different types of energy that can be transferred between objects. When two objects are at different temperatures, it is possible for heat or thermal energy to transfer from one object to the other. If you place a cold pot of water on a hot stove burner, for example, thermal energy will transfer from the stove to the water and the water will get warmer. Heat energy always moves from objects with a high temperature toward objects with a lower temperature.

When we measure the temperature of an object, we often use the Celsius scale. On the Celsius scale water freezes at 0°C and boils at 100°C. The temperature of a substance is a measure of the average kinetic energy of the particles of that substance. Water molecules in a cold sample of water at 10°C have less kinetic energy than water molecules in a sample of hot water at 50°C. In this example, the water molecules at 50°C will be moving faster. If these two samples of water with different temperatures are mixed together, the fast- and slow-moving particles will transfer energy until eventually the molecules all have similar amounts of kinetic energy. When molecules with higher kinetic energy bump into molecules with lower kinetic energy, the faster-moving particles transfer kinetic energy to the slower particles. The transfer of energy will result in the water mixture having a temperature that is in the middle of the starting temperatures, which is called an equilibrium temperature—in this example, perhaps about 30°C.

Whenever substances at different temperatures come into contact with one another, thermal energy will be transferred from the hotter object to the cooler object until an equilibrium temperature is reached. The rate at which that thermal energy is transferred from one substance to another, however, is based on several factors. Some of those factors include the properties of the specific substances, the amount of the substances involved, the starting temperatures, and the size and shape of the objects (see Figure L17.1 on page 306 for three samples of metal with equal mass but different surface areas). In this activity, you will investigate how surface area affects the rate of heat transfer.

## Your Task

Use what you know about thermal energy, tracking energy, and the relationship between structure and function to design and carry out an investigation that will allow you to test how the surface area of a hot object affects the rate at which thermal energy is transferred from that object to water. To complete this task, you will need to heat up several objects with different surface areas and then place them into room-temperature water. It is up to your group to determine how much and at what rate thermal energy is transferred to the room-temperature water.

FIGURE L17.1

**Three samples of metal with equal mass but different surface areas**

The guiding question of this investigation is, **How does the surface area of a substance affect the rate at which thermal energy is transferred from one substance to another?**

## Materials

You may use any of the following materials during your investigation:

**Consumable**
- Water

**Equipment**
- Metal samples
- Hot plate
- Beaker (1,000 ml)
- Graduated cylinder (100 ml)
- Tongs
- Mesh bags
- Styrofoam cups
- Electronic or triple beam balance
- Thermometer or temperature probe
- Ruler
- Stopwatch
- Safety glasses or goggles
- Chemical-resistant apron
- Nonlatex gloves

## Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized indirectly vented chemical-splash goggles and chemical-resistant nonlatex gloves and aprons during lab setup, hands-on activity, and takedown.
2. Use caution when working with hot plates, because they can burn skin and cause fires.

3. Hot plates also need to be kept away from water and other liquids.
4. Use caution when working with hot water, because it can burn skin.
5. Only use GFCI-protected electrical receptacles for hot plates.
6. Clean up any spilled liquid immediately to avoid a slip or fall hazard.
7. Never put consumables in your mouth.
8. Always use tongs to move the heated metal.
9. Handle all glassware with care.
10. Handle glass thermometers with care. They are fragile and can break, causing a sharp hazard that can cut or puncture skin.
11. Never return the consumables to stock bottles.
12. Wash hands with soap and water after completing the lab activity.

## Investigation Proposal Required? ☐ Yes ☐ No

## Getting Started

To answer the guiding question, you will need to design and conduct an investigation to measure the rate at which thermal energy is transferred to the water. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- How will you determine the amount of energy transferred?
- What information or measurements will you need to record?
- How will you know when the equilibrium temperature is achieved?
- How will you measure the surface area of the different samples?
- What variables will you control from one sample to the next?

To determine *how you will collect your data,* think about the following questions:

- What equipment will you need to collect the data you need?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- Are there different ways you can measure the amount of energy transferred?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine *how you will analyze your data,* think about the following questions:

- How will you determine the rate of heat transfer?
- What type of table or graph could you create to help make sense of your data?

## Connections to Crosscutting Concepts, the Nature of Science, and the Nature of Scientific Inquiry

As you work through your investigation, be sure to think about

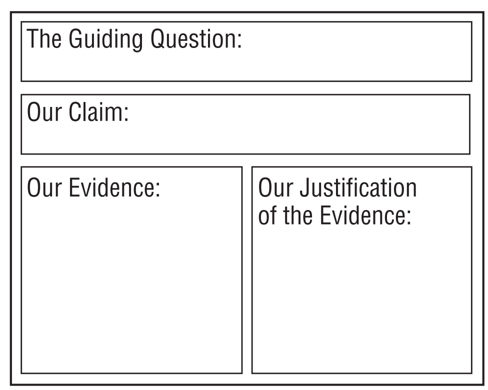
- why it is important to track how energy and matter move into, out of, and within systems;
- how the structure or shape of something can influence how it functions and places limits on what it can and cannot do;
- the difference between observations and inferences in science; and
- the different methods used in science.

## Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a *claim, evidence* to support your claim, and a *justification* of the evidence. The claim is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L17.2.

**FIGURE L17.2**

**Argument presentation on a whiteboard**




## Argumentation Session

The argumentation session allows all of the groups to share their arguments. One member of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so these mistakes can be fixed and they can make their argument better. The argumentation session is also a good time to think about ways you can make your initial argument better. Scientists must share and critique arguments like this to develop new ideas.

To critique an argument, you might need more information than what is included on the whiteboard. You will therefore need to ask the presenter lots of questions. Here are some good questions to ask:

- How did you collect your data? Why did you use that method? Why did you collect those data?
- What did you do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- How did your group analyze the data? Why did you decide to do it that way? Did you check your calculations?
- Is that the only way to interpret the results of your analysis? How do you know that your interpretation of your analysis is appropriate?
- Why did your group decide to present your evidence in that way?
- What other claims did your group discuss before you decided on that one? Why did your group abandon those alternative ideas?
- How confident are you that your claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most acceptable and valid answer to the research question!

## Report

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable and valid!