21. Temperature versus Heat

Driving Questions

What is the relationship between temperature and heat?

Background

Matter, whether liquid, solid, or gas, is made of moving particles. The average kinetic energy of these particles is related to temperature. Because the kinetic energy of each of the individual particles cannot be directly measured, temperature scales, like the Celsius and Fahrenheit scales, are used to measure temperature.

The thermal energy, or internal energy, of a material includes the kinetic energy of the atoms or molecules as well as the potential energy between the atoms and molecules. Heat is a measure of the energy transferred from a hotter material to a cooler material. When we say we are going to "heat something up," we are actually saying we will be causing heat to flow into something to increase the average kinetic energy of its atoms or molecules. Heat will continue to flow from hot materials to cold materials until the temperature of the materials is equal.

Materials and Equipment

For each student or group:

- Data collection system
- Temperature sensor (2)
- Beaker, 600-mL
- Hot plate
- Calorimetry cup (2)
- Copper mass, 200-g (2)
- Aluminum mass, 200-g (2)
- Balance (1 per classroom)
- Vegetable oil, 500 g
- Water, 500 g
- String, 15 cm (4)
- Paper clip, (2)

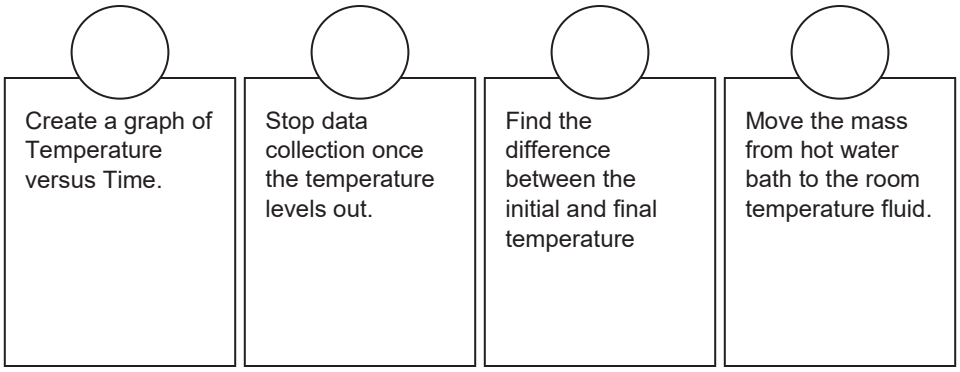
Safety

Add these important safety precautions to your normal laboratory procedures:

- Do not directly touch hot items like the hot plate, beaker, and water.
- Keep the boiling water away from other electrical equipment like a computer.
- Wear an apron, goggles, and gloves as recommended by your teacher.

Sequencing Challenge

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.



Procedure

After you complete a step (or answer a question), place a check mark in the box (☐) next to that step.

Note: When you see the symbol "[2]" with a superscripted number following a step, refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There you will find detailed technical instructions for performing that step. Your teacher will provide you with a copy of the instructions for these operations.

Part 1 – Different Materials in the Same Fluid

Set Up

1. ☐ Measure and record the mass of a copper sample and an aluminum sample in the Data Analysis section.

2. ☐ Why do you think it is important that the mass is similar for the copper and aluminum samples?

_____

_____

3. ☐ Tie approximately 15 cm of string to each of the metal masses.

4. ☐ Carefully place the masses into the 600 mL beaker with the string hanging over the lip of the beaker.

5. ☐ Cut the excess string leaving just enough string so that the masses can be safely lifted out later.

6. ☐ Pour just enough water into the beaker to submerge the masses.

7. ☐ Place the beaker on the hot plate, and then plug-in and turn on the hot plate.

8. ☐ Place the same amount of water in each calorimetry cup.

Note: Make the water level high enough so that the metal sample will be completely submerged when it is placed into the cup; but not so high that the water will overflow.

9. ☐ Use paper clips to attach a temperature sensor to each calorimeter cup so that the tip of each sensor is submerged in water but not touching the wall of the cup.

10. ☐ Why do you think it is important that the mass of water is the same?

_____

_____

11. ☐ Why do you think it is important to use foam calorimetry cups for this experiment?

_____

_____

12. ☐ Start a new experiment on the data collection system. ◆ (1.2)

13. ☐ Connect the temperature sensors to the data collection system. ◆ (2.2)

14. ☐ Display both temperature measurements on the *y*-axis of a graph with Time on the *x*-axis. ◆ (7.1.10)

15. ☐ What is a good method of making sure the temperature of the water is the same in each cup?

_____

_____

16. ☐ Make sure the temperature of the water in the calorimetry cups is the same temperature.

17. ☐ Why do you think it is important that the temperature of the water is the same?

_____

_____

Note: Remember to make sure the mass of the water in each cup is the same when done.

Collect Data

18. ☐ When the water bath starts boiling, start data recording. ◆ (6.2)

Note: Keep the water bath hot for Part 2.

19. ☐ Carefully transfer the masses from the water bath to the calorimetry cups. One mass in each cup

20. ☐ After a few minutes, when the Temperature versus Time plot levels off, stop data recording. ◆ (6.2)

Analyze Data

21. ☐ For each metal sample, find the initial water temperature (minimum) and the final water temperature (maximum), and record them into Table 1 in the Data Analysis section. ◆ (9.4)

Part 2 – Similar Materials in Different Fluids

Set Up

22. ☐ Measure and record the mass of two samples of the same metal in the Data Analysis section.

23. ☐ Why do you think it is important that the samples are made of the same materials and have the same mass?

_____

_____

24. ☐ Tie approximately 15 cm of string to each of the metal masses.

25. ☐ Carefully place the masses into the 600 mL beaker filled with hot water with the string hanging over the lip of the beaker.

26. ☐ Cut the excess string leaving just enough string so that the masses can be safely lifted out later.

27. ☐ Turn up the hot plate so that the water will return to a boil.

28. ☐ Place vegetable oil in one of the calorimetry cups, and place the same mass of water as vegetable oil in the other calorimetry cup.

Note: Make the fluid level high enough so that the sample will be completely submerged when it is placed into the cup; but not so high that the fluid overflows.

29. ☐ Use paper clips to attach a temperature sensor to each cup so that the tip of each sensor is submerged in fluid but not touching the wall of the cup.

30. ☐ Monitor the temperature in the cups without recording. ◆ (6.1)

31. ☐ Why do you think it is important that the mass of fluid is the same?

_____

_____

32. ☐ What is a good method of making sure the temperature of the fluid is the same in each cup?

_____

_____

_____

33. ☐ Adjust the temperature of the water to match that of the vegetable oil.

34. ☐ Why do you think it is important that the temperature of the fluids is the same?

_____

_____

35. ☐ Stop monitoring live data, and return to your graph display.

Collect Data

36. ☐ When the water bath starts boiling, start recording data. ◆ (6.2)

37. ☐ Turn off the hot plate.

38. ☐ Carefully transfer the masses from the water bath to the calorimetry cups, one mass in each cup.

39. ☐ After a few minutes, when the Temperature versus Time plot levels off, stop data recording. ◆ (6.2)

Analyze Data

40. ☐ For each liquid sample, find the initial temperature (minimum) and the final temperature (maximum), and record those values into Table 3 in the Data Analysis section. ◆ (9.4)

41. ☐ Save your experiment as instructed by your teacher. ◆ (11.1)

Data Analysis

Part 1: Mass of the metal samples

Mass Aluminum: _____ Mass Copper: _____

Table 1: Different Metal Samples

Metal Sample	Initial Temperature (°C)	Final Temperature (°C)
Water with Aluminum		
Water with Copper		

1. ☐ Calculate the change in temperature for each sample, and enter the change in Table 2.

Table 2: Change in Temperature, Part 1

Sample	Change in Temperature (°C)
Water with Aluminum	
Water with Copper	

Part 2: Mass of the metal samples

Mass Sample 1: _____ Mass Sample 2: _____

Table 3: Different Fluids, Part 2

Fluid	Initial Temperature (°C)	Final Temperature (°C)
Vegetable Oil		
Water		

2. ☐ Calculate the change in temperature for each sample, and enter the change in Table 4.

Table 4: Change in Temperature, Part 2

Sample	Change in Temperature (°C)
Vegetable Oil	
Water	

Analysis Questions

1. In each case where you started with a metal that was hot and a liquid at room temperature, what happened to the temperature of the liquid? What does this tell you about the flow of heat?

2. How does the change in water temperature compare for the different metals submerged in the same amount of water?

3. The temperature change of the water represents the change in the water's internal energy. Compare the amount of heat delivered by the different metal samples submerged in water. Explain your answer.

4. **The initial temperature of the metal samples was the same, and the initial temperature of the water in the cups was the same. Because the final temperature of the water in the different cups is different, what does this tell you about internal energy of the metal samples when they are at the same temperature in the water bath? Explain?**

5. **What does the answer from the previous question tell you about the temperature and heat of two different metals?**

6. **How does the change in temperature compare for the same metal submerged in different fluids?**

7. **The copper samples are the same material at the same temperature initially. Therefore, they must start out with the same internal energy. Compare how the heat from the metal samples affects the liquids they are submerged in. Explain your answer.**

Synthesis Questions

Use available resources to help you answer the following questions.

1. What is the difference between heat and temperature?

_____

_____

_____

2. Imagine you have two copper samples, one that is 100 g and one that is 200 g, each at a temperature of 85 °C. If each sample is placed into a cup of room-temperature water, which cup will be the hottest after they both reach equilibrium? Explain.

_____

_____

_____

Multiple Choice Questions

Select the best answer or completion to each of the questions or incomplete statements below.

1. A 200 g mass of copper at 150 °C is placed on top of a 400 g mass of aluminum at 20 °C. The internal energy of the aluminum increases because

- **A.** Heat transfers from the aluminum to the copper.
- **B.** Heat transfers from the copper to the aluminum.
- **C.** The average kinetic energy of the copper increases.
- **D.** It begins to melt.

2. Which of the following best describes heat?

- **A.** The amount of translational kinetic energy in a material
- **B.** The average kinetic energy in a material
- **C.** The total energy in a material
- **D.** The transfer of energy from one material to another without work being done

Key Term Challenge

Fill in the blanks from the list of randomly ordered words in the Key Term Challenge Word Bank.

1. Two common temperature scales used in science are the _____ and _____ scales. Temperature is related to the average _____ of the particles in a material. Kinetic energy depends upon the mass and _____ of particles. The particles move in different ways. Some particles may have _____ or straight-line motion, while others may vibrate or even spin.

2. The word "heat" is loosely used in common language. However, in science it specifically relates to the _____ of energy from one material to another. Sometimes the term "heat" is used interchangeably with the term "thermal energy." Thermal energy is in fact the total amount of _____ contained in a material. Heat transfers spontaneously from a _____ object to a _____ object.

Key Term Challenge Word Bank

Paragraph 1	Paragraph 2
Celsius	Average
Kelvin	Cold
Kinetic Energy	Constant
Thermal	Energy
Translational	Heat
Velocity	Hot
Vertical	Linear
Vibrate	Transfer