Name: _____ Date: _____

Student Exploration: Calorimetry Lab

Vocabulary: calorie, calorimeter, joule, specific heat capacity

Prior Knowledge Questions (Do these BEFORE using the Gizmo.)

1. The Latin word *calor* means "heat," and *meter* comes from the Greek word meaning "to measure." What do you think a **calorimeter** does? _____

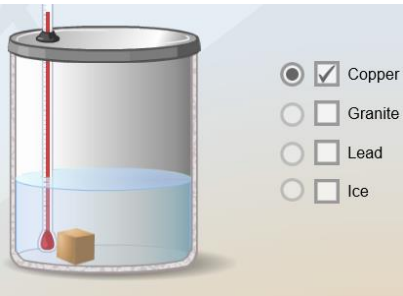
   _____

2. Where have you heard the word **calorie** before? What do you think a calorie is? _____

   _____

Gizmo Warm-up

A calorimeter is an insulated container filled with a liquid, usually water. When a hot object is placed in the calorimeter, heat energy is transferred from the object to the water and the water heats up.



Calorimeters can be used to find a substance's **specific heat capacity**. You will use the *Calorimetry Lab* Gizmo™ to determine the specific heat capacities of various substances.

1. On the SIMULATION pane, select **Copper**. Use the slider to set its **Mass** to 200 g. Set the **Water mass** to 200 g. Check that the **Water temp** is set to 30.0 °C and the copper's **Temp** is 90 °C. Select the GRAPH tab, and click **Play** (▶).

   A. What was the **Final temperature** of the copper and the water? _____

   B. How much did the temperature of the copper change? _____

   C. How much did the temperature of the water change? _____

2. Specific heat capacity can be described as a substance's resistance to temperature changes. Which substance has a greater specific heat capacity, copper or water? Explain.

   _____

   _____

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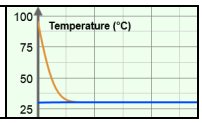
Activity A: **Heat transfer**	Get the Gizmo ready: • Click **Reset** (↺).	

Question: What factors determine how heat energy transfers between objects?

1. Predict: In the Gizmo warm-up, you saw how 200 g of 90 °C copper transfers heat to 200 g of 30.0 °C water.

   A. How do you think increasing the water's mass would affect the final temperature?

   _____

   _____

   B. How do you think decreasing the copper's mass would affect the final temperature?

   _____

   _____

   C. How do you think increasing or decreasing the copper's initial temperature would affect the final temperature? _____

   _____

2. Collect data: Use the Gizmo to determine the final temperature for each set-up listed below. Record your results in the tables. In the first table, you experiment with changing the water's mass. In the second table, you change the copper's mass. In the third table, you change the initial temperature of the copper. The first row of each table has been completed for you.

Copper		Water		Final Temp. (°C)
Initial Temp. (°C)	**Mass (g)**	**Initial Temp. (°C)**	**Mass (g)**	
90 °C	200 g	30.0 °C	200 g	34.96 °C
90 °C	200 g	30.0 °C	2,000 g	
90 °C	200 g	30.0 °C	200 g	34.96 °C
90 °C	20 g	30.0 °C	200 g	
90 °C	200 g	30.0 °C	200 g	34.96 °C
100 °C	200 g	30.0 °C	200 g	
50 °C	200 g	30.0 °C	200 g	

(Activity A continued on next page)

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Activity A (continued from previous page)

3. Analyze: For each factor listed in the chart below, explain how the final temperature was changed and why you think that change occurred.

   A. What was the effect of increasing the water's mass? _____

   _____

   B. What was the effect of decreasing the copper's mass? _____

   _____

   C. What was the effect of changing the initial temperature of the copper? _____

   _____

   _____

4. Draw conclusions: The amount that the water's temperature increases depends on the mass of the water and the amount of heat energy in the copper.

   A. How does changing the initial mass of the copper affect how much heat energy it has? _____

   _____

   B. How does changing the initial temperature of the copper affect how much heat energy it has? _____

   _____

5. Apply: Many gyms and health clubs have steam saunas, which are small steam-filled rooms. Traditionally, steam saunas have a container of heated rocks. A small ladle of water is poured on the rocks in order to make the steam.

   A. Use what you have learned so far about heat transfer to explain how hot rocks can be used to make steam? _____

   _____

   B. Why do you think only a small ladle-full of water is poured on the rocks at one time?

   _____

   _____

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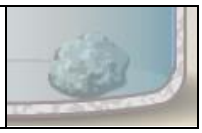
Activity B: **Specific heat**	Get the Gizmo ready: • Click **Reset**. • Deselect **Copper**, and select **Granite**.	

Question: How can you compare the specific heat capacities of various substances?

1. Explain: How do you think you can use the calorimeter to compare the specific heat capacities of the substances listed on the Gizmo? _____

   _____

   _____

2. Predict: Which substance do you think will have the highest specific heat capacity? Why?

   _____

   _____

3. Experiment: Use the Gizmo to determine the final temperature for each set-up listed below. Record your results in the table. The first row has been completed for you.

Substance	Substance initial temp. (°C)	Substance mass	Water initial temp. (°C)	Water mass	Final temp. (°C)
Copper	90 °C	200 g	30.0 °C	200 g	34.96 °C
Granite	90 °C	200 g	30.0 °C	200 g	
Lead	90 °C	200 g	30.0 °C	200 g	

4. Analyze: Of the three substances, which caused the largest temperature change in the water? What does this indicate about its relative specific heat capacity? _____

   _____

5. Interpret: Remember that specific heat capacity is a measure of a substance's resistance to temperature change. The more resistant a substance is to temperature change, the higher is its specific heat capacity.

   Rank the three substances in order of their specific heat capacities, from highest to lowest.

   _____

(Activity B continued on next page)

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Activity B (continued from previous page)

6. Predict: How do you think the specific heat capacity of ice will compare to that of copper, granite, and lead? _____

_____

7. Experiment: Deselect **Lead**, and select **Ice**. Use the default values for **Temp** (-30 °C) and **Mass** (50 g). Set the **Water temp** to 60 °C and the **Water mass** to 200 g. Click **Play**.

   A. What was the final temperature? _____

   B. What do you think is happening when the ice line on the graph is at 0 °C for a long period of time? Why do you think the line disappears after that? _____

   _____

   C. How much of a temperature change did the water experience? _____

   D. How does this change in the water's temperature compare to the change caused by the other substances you tested? _____

8. Extend your thinking: A lot of energy is needed to heat a substance with a high specific heat capacity. However, even more energy is needed to cause a phase change (such as the melting of ice). Click **Reset**. Set the ice's **Temp** to -100 °C and its **Mass** to 50 g. Set the **Water temp** to 50 °C and **Water mass** to 200 g. Click **Play**.

   A. What was the final temperature? _____

   B. Do you think all the ice melted? Explain. _____

   _____

   C. Look at the GRAPH. The graph shows two separate stages: the heating of the ice and then the melting of the ice. How much did the water's temperature change while the ice was heating? How much did it change while the ice was melting?

   _____

   _____

   D. How did this experiment demonstrate ice's high specific heat capacity? _____

   _____

   _____

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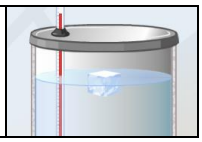
Activity C: **Calculating specific heat**	Get the Gizmo ready: • Click **Reset**.	

Introduction: The specific heat capacity of a substance is the amount of energy needed to change the temperature of that substance by 1 °C. Specific heat capacity can be calculated using the following equation:

$$q = mc\Delta T$$

In the equation q represents the amount of heat energy gained or lost (in **joules**), m is the mass of the substance (in grams), c is the specific heat capacity of the substance (in J/g °C), and ΔT is the temperature change of the substance (in °C).

Goal: Calculate the specific heat capacities of copper, granite, lead, and ice.

1. Solve: When you mix two substances, the heat gained by one substance is equal to the heat lost by the other substance. Suppose you place 125 g of aluminum in a calorimeter with 1,000 g of water. The water changes temperature by 2 °C and the aluminum changes temperature by –74.95 °C.

   A. Water has a known specific heat capacity of 4.184 J/g °C. Use the specific heat equation to find out how much heat energy the water gained (q).

   _____

   B. Assume that the heat energy gained by the water is equal to the heat energy lost by the aluminum. Use the specific heat equation to solve for the specific heat of aluminum. (Hint: Because heat energy is lost, the value of q is negative.)

   _____

   Aluminum's accepted specific heat value is 0.900 J/g °C. Use this value to check your work.

2. Calculate: Use the Gizmo to mix 200 g of copper at 100 °C with 1,000 g of water at 20 °C.

   A. What is the final temperature? _____

   B. Calculate the temperature change of each substance by subtracting the initial temperature from the final temperature.

   ΔT_{water}: _____ ΔT_{copper}: _____

   C. How much heat energy (q) did the water gain? _____

   D. Now solve for the specific heat (c) of copper: _____

(Activity C continued on next page)

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Activity C (continued from previous page)

3. Calculate: Use the Gizmo to mix 200 g of granite at 100 °C with 1,000 g of water at 20 °C.

   A. What is the final temperature? _____

   B. Calculate the temperature change of each substance by subtracting the initial temperature from the final temperature.

   ΔT_{water}: _____ $\Delta T_{granite}$: _____

   C. How much heat energy (q) did the water gain? _____

   D. Now solve for the specific heat (c) of granite: _____

   E. Repeat steps A through D to find the specific heat (c) of lead: _____

4. Challenge: Use the specific heat capacity that you calculated for granite to determine how many grams of granite at the initial temperature of 80 °C must mix with 3,000 g of water at the initial temperature of 20 °C to result in a final system temperature of 20.45 °C. (Hint: Start by calculating how much heat energy is needed to change the water's temperature by 0.45 °C). Show your work. Use the Gizmo to check your answer.

   Mass of granite = _____

5. Extend your thinking: In addition to calculating specific heat capacities, some calorimeters can be used to determine how much energy is in food. The energy in food is usually expressed in calories or kilocalories (Calories). A calorie is the amount of energy needed to change the temperature of 1 g of water by 1 C. There are 1,000 calories in a Calorie.

   A. How many joules are in 1 calorie? (The specific heat of water is 4.184 J/g °C.)

   _____

   B. Suppose a snack bar is burned in a calorimeter and heats 2,000 g water by 20 °C. How much heat energy was released? (Hint: Use the specific heat equation.) Give your answer in both joules and calories.

   _____

   C. How many kilocalories (Calories) does the snack bar contain? _____

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