Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

$$\mathbf{q = (m_{water})(\Delta T)(4.184\ J/g\ {}^\circ C)}$$

To measure specific heat in the laboratory, a **calorimeter** is used. A calorimeter is a well-insulated container used in measuring energy changes. The calorimeter contains water and is insulated to reduce the loss or gain of energy to or from the surroundings. Energy always flows from a substance at a higher temperature to a substance at a lower temperature. The heat gained by the cooler substance equals the heat lost by the warmer substance, if we assume no loss of heat to the air outside the calorimeter.

heat lost by "system" = heat gained by water

Target:

In this experiment, you will determine the specific heat for a given metal. The metal sample will be heated to a high temperature then placed into a coffee cup calorimeter containing a known amount of water. If you can find out how much heat was gained by the water in the calorimeter than you will know how much heat was lost by the metal.

Heat lost by the metal, q_{metal} = - (Heat gained by the water, q_{H2O})

You will be able to solve for the specific heat capacity of the metal (c_{metal}) because everything else in the equation will be measured or known.

Prelaboratory Assignment

Read the **Introduction** and **Procedure** before you begin. Answer the Prelaboratory Questions.

1. Since the specific heat of water is given in units of joules per *gram* degree Celsius why do we measure the volume of water in the calorimeter instead of its mass?
2. A 22.50-g piece of an unknown metal is heated to 100.°C then transferred quickly and without cooling into 100. mL of water at 20.0°C. The final temperature reached by the system is 26.9°C.
    a. Calculate the quantity of heat absorbed by the water. Show all work.
    b. Determine the quantity of heat lost by the piece of metal. Show all work.
    c. Calculate the specific heat of the metal in J/g °C. Show all work.
3. What would be the effect on the value of the specific heat capacity of water if all temperatures were measured in kelvins (K) rather than degrees Celsius (°C)? Explain.

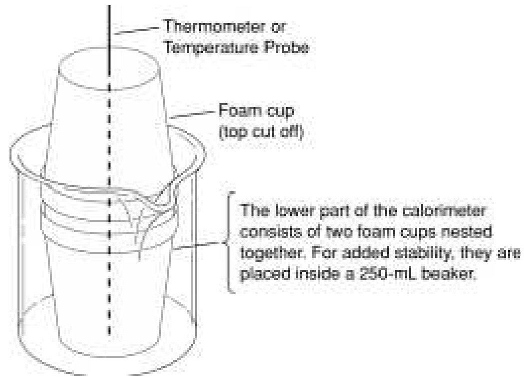
Materials

balance	250-mL beaker (2)	Safety goggles
Tap water	Thermometer	Lab apron
Foam cups, 6 oz (2)	50-mL graduated cylinders	Hot pad or mitt
Metal sample	Hot plate	

Procedure

Calorimeter Apparatus

The calorimeter used in this experiment is made of two white foam polystyrene coffee cups. Foam polystyrene, as you know from experience, is an excellent insulator. Stack two Styrofoam cups, pierce the bottom of the top cup to insert a thermometer. The thermometer should touch the bottom of the inner cup. Make a tight-fitting hole for the thermometer. (See **Figure 1**.)



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The calorimeter

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4. Quickly and carefully transfer the metal sample at 100°C to the room temperature water in the calorimeter. Quickly place the lid containing the thermometer back on the calorimeter.
5. Note and record the highest temperature reached by the contents of the calorimeter.
6. Repeat the experiment two more times, starting with fresh, cool water in the calorimeter and a dry sample metal.

Data Table:

	Trial 1	Trial 2	Trial 3
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Initial temp of metal sample	100 ºC	100 ºC	100 ºC
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Questions and Analysis

1. Calculate the quantity of heat gained by the water, using **$q = (m_{water})(\Delta T)(4.184$ J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
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a. Explain why the assumption is not valid.
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4. Look up the value of the specific heat of your metal in the *Handbook of Chemistry and Physics.* Calculate your percent error, using the following equation (note the "absolute value" signs).

$$\% \text{ error} = \frac{(\text{accepted value}) - (\text{experimental value})}{(\text{accepted value})} \text{ X100} =$$

5. Any calorimeter absorbs a certain amount of the heat released. Knowing this, is your value of the specific heat of the metal more likely to be higher or lower than the accepted value? Explain.

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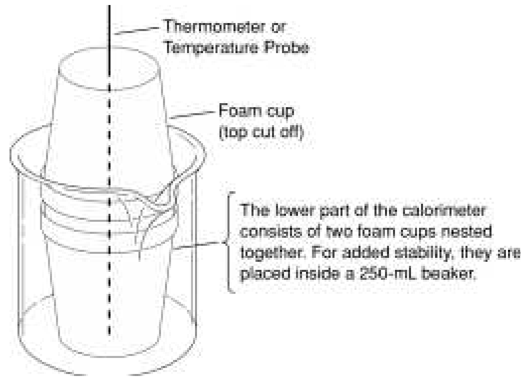

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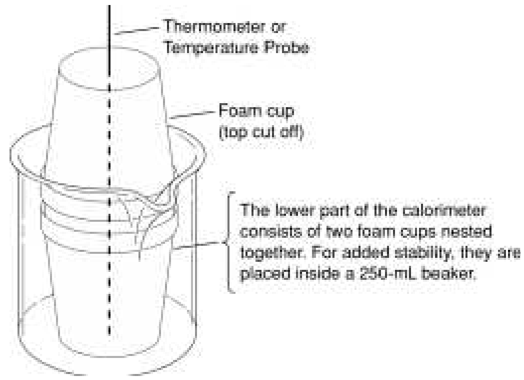

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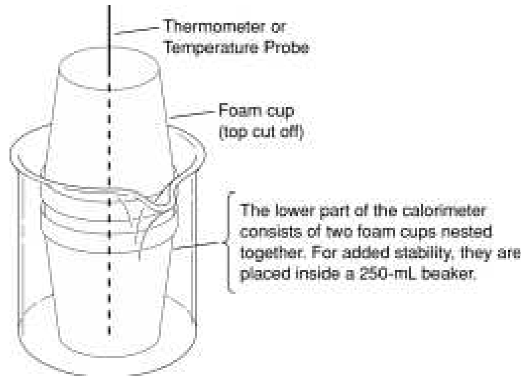

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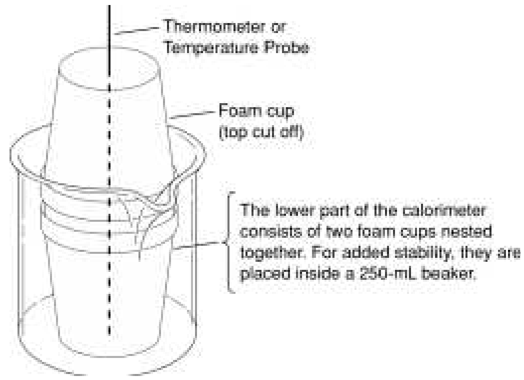

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1. Calculate the quantity of heat gained by the water, using **$q = (m_{water})(\Delta T)(4.184$ J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
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Conclusion:

Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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Materials

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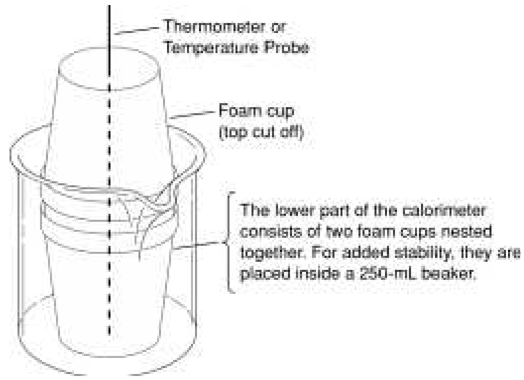

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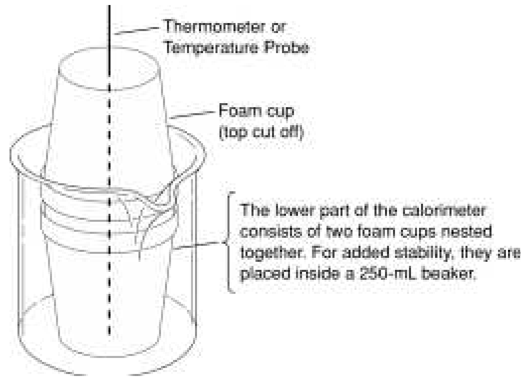

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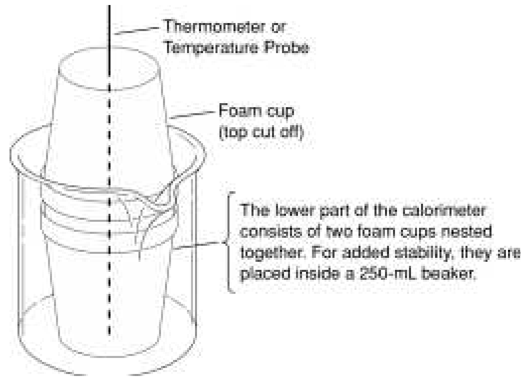

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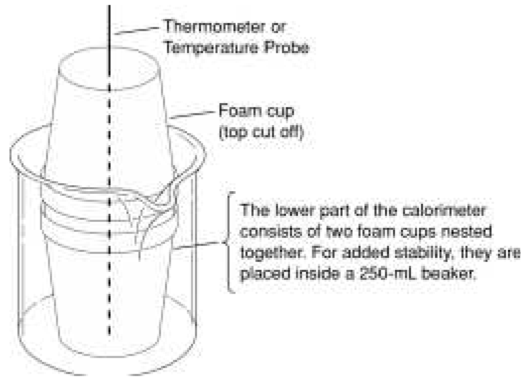

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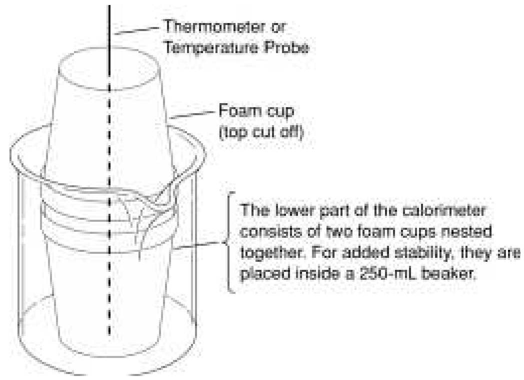

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3. Obtain a metal sample. Note and record the mass of the metal sample in your Data Table. Place the metal sample in the boiling water bath for about 3 minutes. This is to ensure that the temperature of the metal is 100°C, the temperature of boiling water. **Note: The metal sample is hot. Use beaker tongs to QUICKLY remove your metal sample from the boiling water.**
4. Quickly and carefully transfer the metal sample at 100°C to the room temperature water in the calorimeter. Quickly place the lid containing the thermometer back on the calorimeter.
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	Trial 1	Trial 2	Trial 3
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Questions and Analysis

1. Calculate the quantity of heat gained by the water, using **q = (m$_{water}$)(ΔT)(4.184 J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
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Conclusion:

Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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heat lost by "system" = heat gained by water

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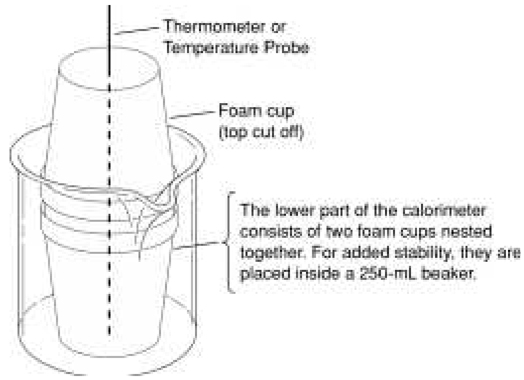

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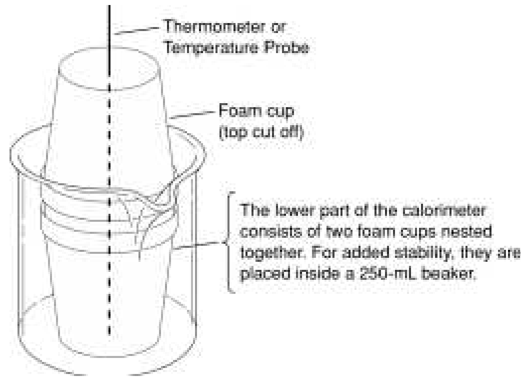

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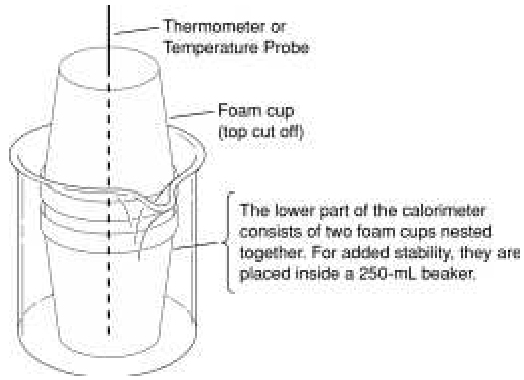

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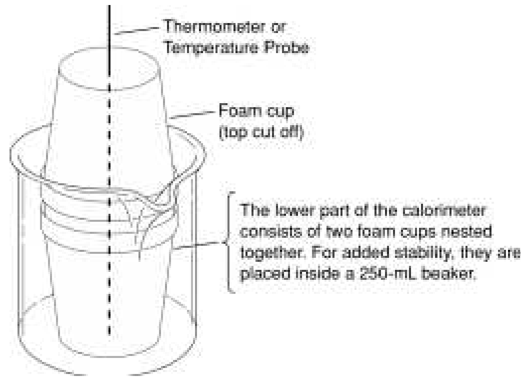

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3. What would be the effect on the value of the specific heat capacity of water if all temperatures were measured in kelvins (K) rather than degrees Celsius (°C)? Explain.

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balance	250-mL beaker (2)	Safety goggles
Tap water	Thermometer	Lab apron
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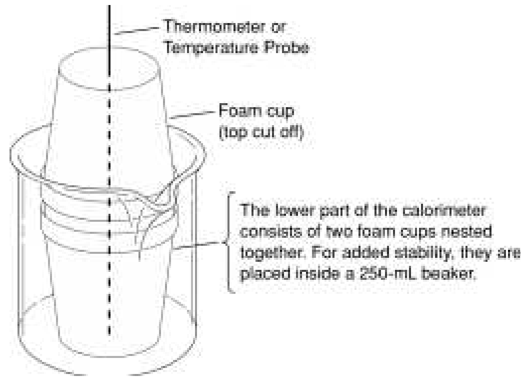
The calorimeter used in this experiment is made of two white foam polystyrene coffee cups. Foam polystyrene, as you know from experience, is an excellent insulator. Stack two Styrofoam cups, pierce the bottom of the top cup to insert a thermometer. The thermometer should touch the bottom of the inner cup. Make a tight-fitting hole for the thermometer. (See **Figure 1**.)



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1. Calculate the quantity of heat gained by the water, using **$q = (m_{water})(\Delta T)(4.184$ J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
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5. Any calorimeter absorbs a certain amount of the heat released. Knowing this, is your value of the specific heat of the metal more likely to be higher or lower than the accepted value? Explain.

Conclusion:

Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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In this experiment, you will determine the specific heat for a given metal. The metal sample will be heated to a high temperature then placed into a coffee cup calorimeter containing a known amount of water. If you can find out how much heat was gained by the water in the calorimeter than you will know how much heat was lost by the metal.

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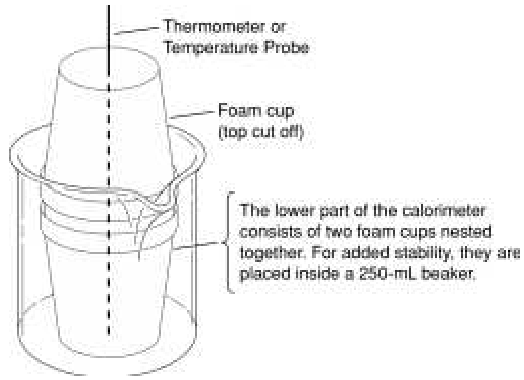

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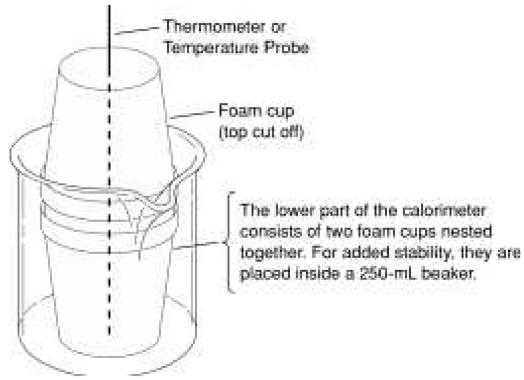

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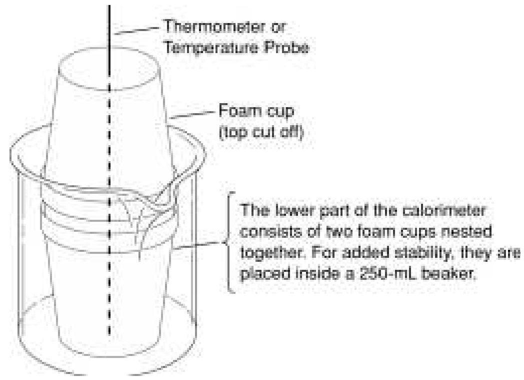

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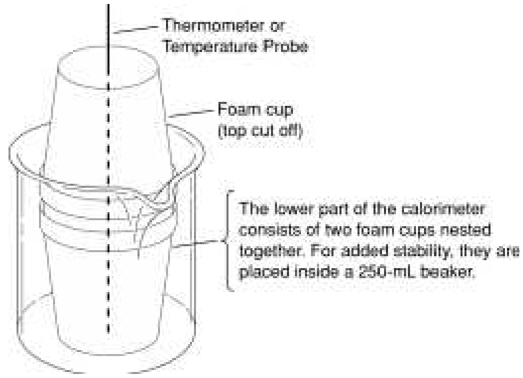

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heat lost by "system" = heat gained by water

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In this experiment, you will determine the specific heat for a given metal. The metal sample will be heated to a high temperature then placed into a coffee cup calorimeter containing a known amount of water. If you can find out how much heat was gained by the water in the calorimeter than you will know how much heat was lost by the metal.

Heat lost by the metal, q_{metal} = - (Heat gained by the water, q_{H2O})

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   a. Calculate the quantity of heat absorbed by the water. Show all work.
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3. What would be the effect on the value of the specific heat capacity of water if all temperatures were measured in kelvins (K) rather than degrees Celsius (°C)? Explain.

Materials

balance	250-mL beaker (2)	Safety goggles
Tap water	Thermometer	Lab apron
Foam cups, 6 oz (2)	50-mL graduated cylinders	Hot pad or mitt
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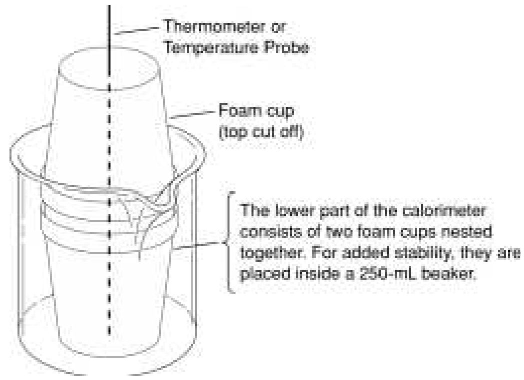
The calorimeter used in this experiment is made of two white foam polystyrene coffee cups. Foam polystyrene, as you know from experience, is an excellent insulator. Stack two Styrofoam cups, pierce the bottom of the top cup to insert a thermometer. The thermometer should touch the bottom of the inner cup. Make a tight-fitting hole for the thermometer. (See **Figure 1**.)



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5. Any calorimeter absorbs a certain amount of the heat released. Knowing this, is your value of the specific heat of the metal more likely to be higher or lower than the accepted value? Explain.

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Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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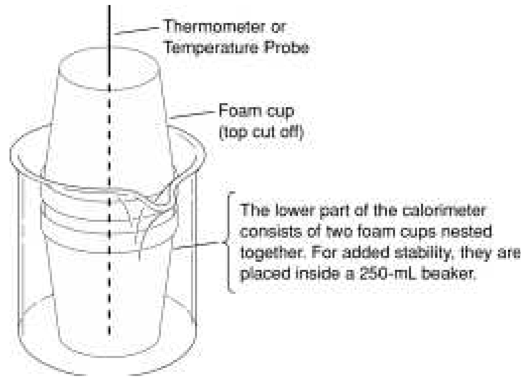

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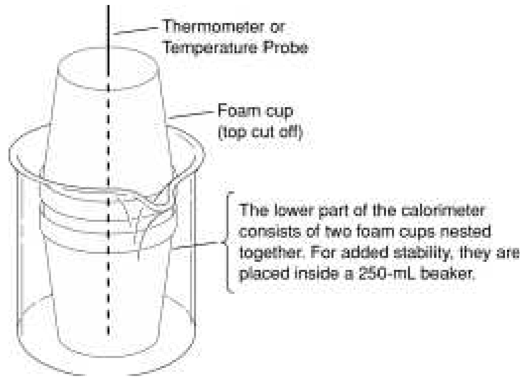

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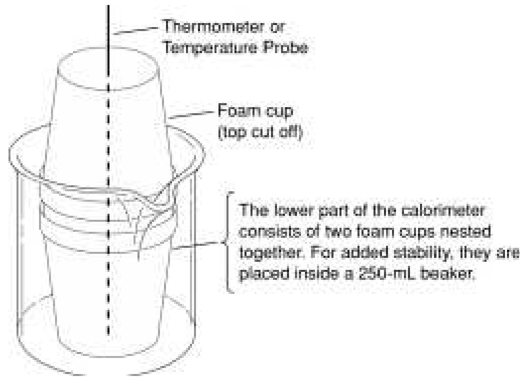

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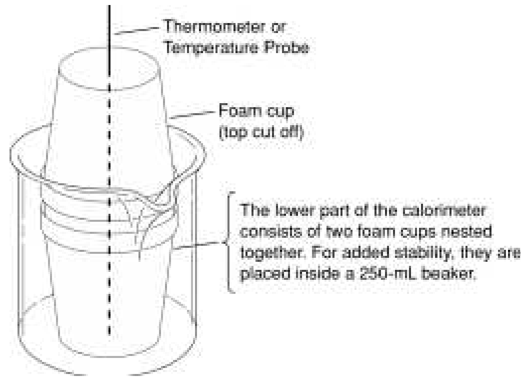

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1. Calculate the quantity of heat gained by the water, using **$q = (m_{water})(\Delta T)(4.184$ J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
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5. Any calorimeter absorbs a certain amount of the heat released. Knowing this, is your value of the specific heat of the metal more likely to be higher or lower than the accepted value? Explain.

Conclusion:

Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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heat lost by "system" = heat gained by water

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Materials

balance	250-mL beaker (2)	Safety goggles
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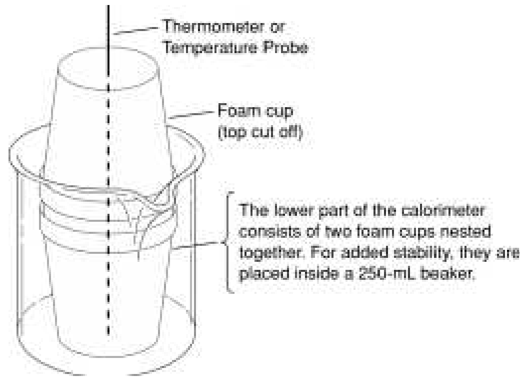

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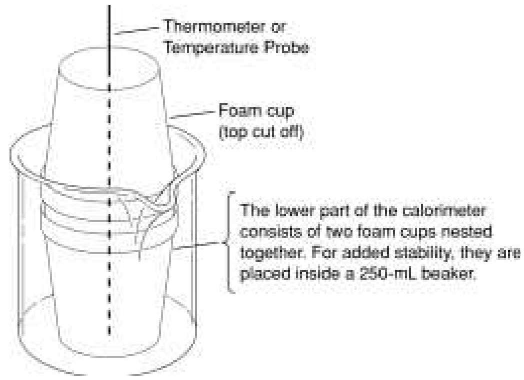

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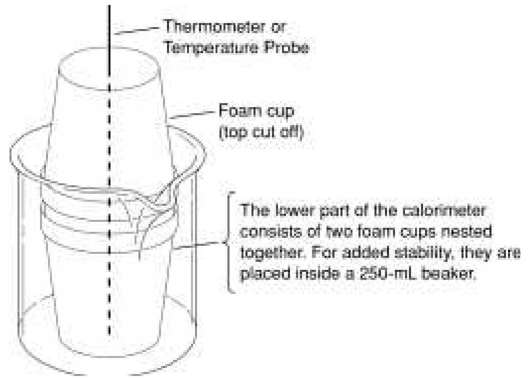

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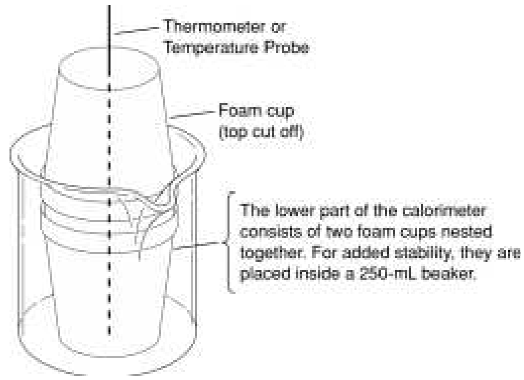

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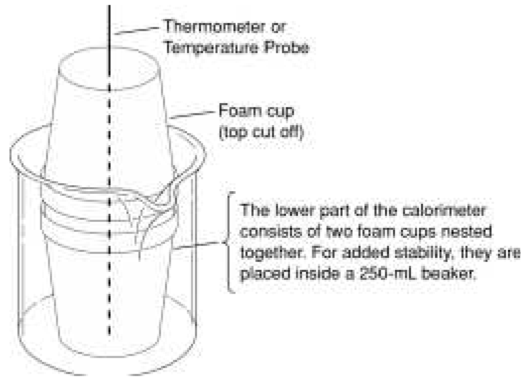

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4. Quickly and carefully transfer the metal sample at 100°C to the room temperature water in the calorimeter. Quickly place the lid containing the thermometer back on the calorimeter.
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Initial temp of metal sample	100 ºC	100 ºC	100 ºC
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1. Calculate the quantity of heat gained by the water, using **$q = (m_{water})(\Delta T)(4.184$ J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
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5. Any calorimeter absorbs a certain amount of the heat released. Knowing this, is your value of the specific heat of the metal more likely to be higher or lower than the accepted value? Explain.

Conclusion:

Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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heat lost by "system" = heat gained by water

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In this experiment, you will determine the specific heat for a given metal. The metal sample will be heated to a high temperature then placed into a coffee cup calorimeter containing a known amount of water. If you can find out how much heat was gained by the water in the calorimeter than you will know how much heat was lost by the metal.

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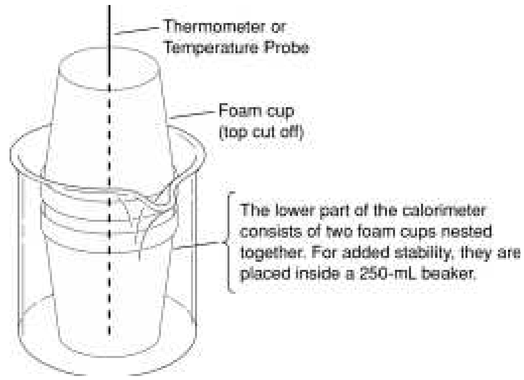

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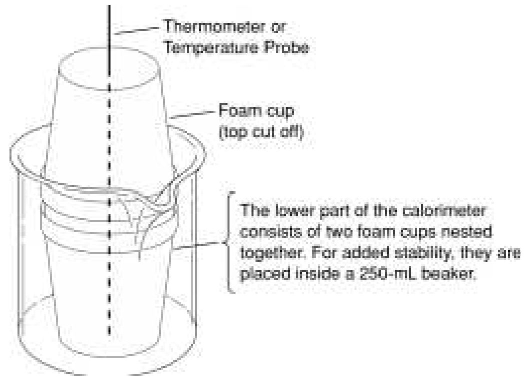

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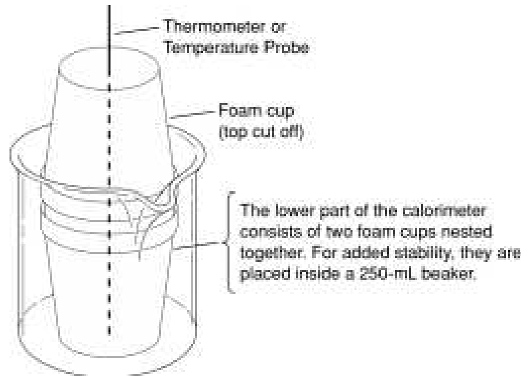

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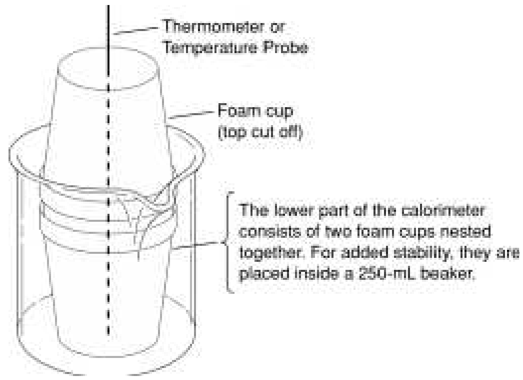

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   c. Calculate the specific heat of the metal in J/g °C. Show all work.
3. What would be the effect on the value of the specific heat capacity of water if all temperatures were measured in kelvins (K) rather than degrees Celsius (°C)? Explain.

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balance	250-mL beaker (2)	Safety goggles
Tap water	Thermometer	Lab apron
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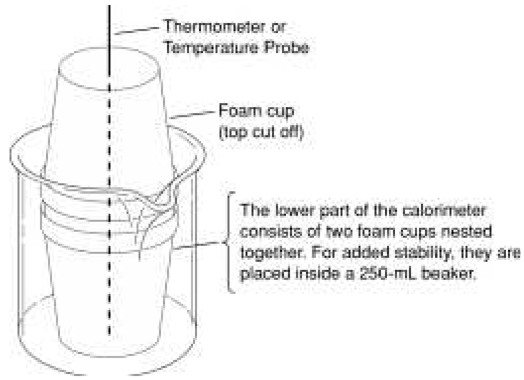
The calorimeter used in this experiment is made of two white foam polystyrene coffee cups. Foam polystyrene, as you know from experience, is an excellent insulator. Stack two Styrofoam cups, pierce the bottom of the top cup to insert a thermometer. The thermometer should touch the bottom of the inner cup. Make a tight-fitting hole for the thermometer. (See **Figure 1**.)



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1. Calculate the quantity of heat gained by the water, using **$q = (m_{water})(\Delta T)(4.184$ J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
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<u>Conclusion:</u>

Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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heat lost by "system" = heat gained by water

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In this experiment, you will determine the specific heat for a given metal. The metal sample will be heated to a high temperature then placed into a coffee cup calorimeter containing a known amount of water. If you can find out how much heat was gained by the water in the calorimeter than you will know how much heat was lost by the metal.

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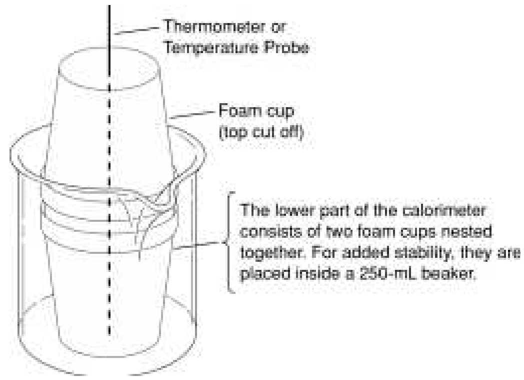

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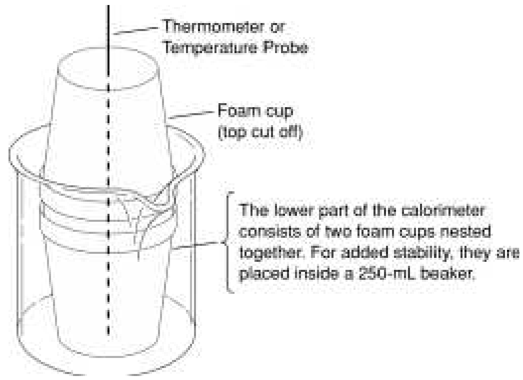

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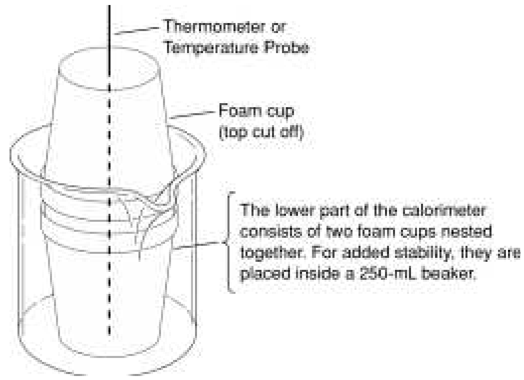

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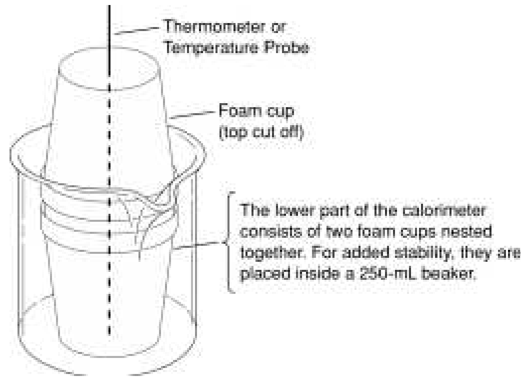

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heat lost by "system" = heat gained by water

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In this experiment, you will determine the specific heat for a given metal. The metal sample will be heated to a high temperature then placed into a coffee cup calorimeter containing a known amount of water. If you can find out how much heat was gained by the water in the calorimeter than you will know how much heat was lost by the metal.

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   a. Calculate the quantity of heat absorbed by the water. Show all work.
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3. What would be the effect on the value of the specific heat capacity of water if all temperatures were measured in kelvins (K) rather than degrees Celsius (°C)? Explain.

Materials

balance	250-mL beaker (2)	Safety goggles
Tap water	Thermometer	Lab apron
Foam cups, 6 oz (2)	50-mL graduated cylinders	Hot pad or mitt
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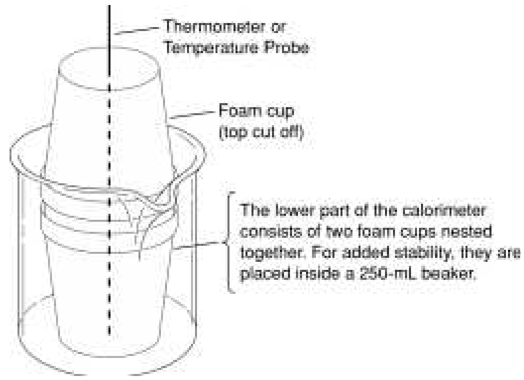
The calorimeter used in this experiment is made of two white foam polystyrene coffee cups. Foam polystyrene, as you know from experience, is an excellent insulator. Stack two Styrofoam cups, pierce the bottom of the top cup to insert a thermometer. The thermometer should touch the bottom of the inner cup. Make a tight-fitting hole for the thermometer. (See **Figure 1**.)



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5. Any calorimeter absorbs a certain amount of the heat released. Knowing this, is your value of the specific heat of the metal more likely to be higher or lower than the accepted value? Explain.

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Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g °C. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

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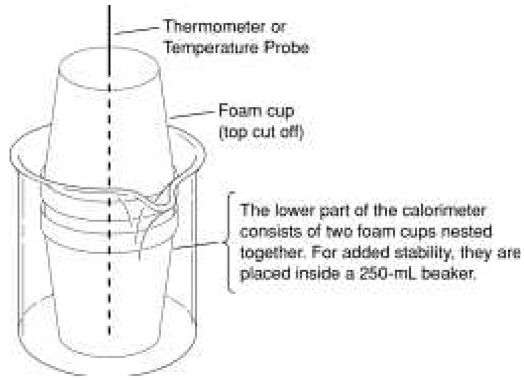

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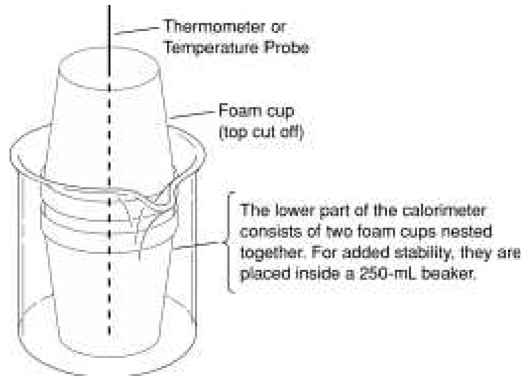

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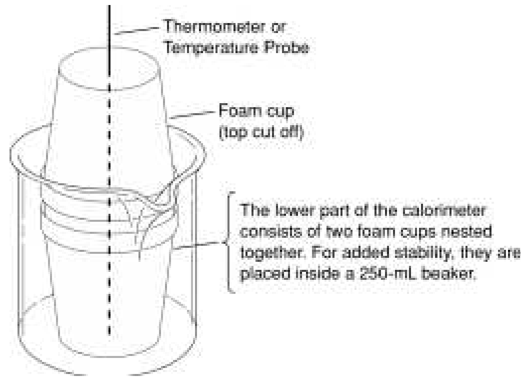

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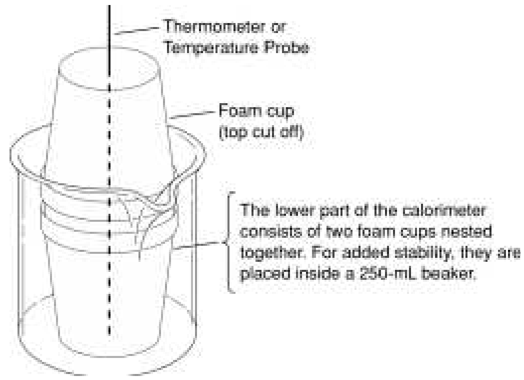

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ΔT of metal (Final $_{metal}$ – Initial $_{metal}$)			

Questions and Analysis

1. Calculate the quantity of heat gained by the water, using **$q = (m_{water})(\Delta T)(4.184$ J/g °C)** Report the results of all trials, as well as an average (mean) value. You need to show your work for all of the trials.
2. Assume that the quantity of heat lost by the metal is equal to the quantity of heat gained by the water. Use $q = (m_{water})(\Delta T)(4.184$ J/g °C) and $Q = C_p \times m \times \Delta T$ (solve for C_p) to determine the specific heat, $\mathbf{C_p}$, of the metal. Be sure you use ΔT for the metal in your calculation. Report the result for each trial, as well as a mean value. Show the calculations all trials. Determine the metal you have….
3. Consider the assumption you were asked to make in **2**.

a. Explain why the assumption is not valid.
b. Does using the assumption in **2** give a value for the specific heat of the metal that is too high or too low? Explain.

4. Look up the value of the specific heat of your metal in the *Handbook of Chemistry and Physics.* Calculate your percent error, using the following equation (note the "absolute value" signs).

$$\% \text{ error} = \frac{(\text{accepted value}) - (\text{experimental value})}{(\text{accepted value})} \text{ X100} =$$

5. Any calorimeter absorbs a certain amount of the heat released. Knowing this, is your value of the specific heat of the metal more likely to be higher or lower than the accepted value? Explain.

Conclusion:

Specific Heat of a Metal

Background:

Specific heat capacity is the amount of energy, measured in calories or joules, needed to raise the temperature of 1 g of the substance by 1 °C. **Water was chosen as the standard and assigned a specific heat of 1.00 cal/g** °C**. The specific heat capacities of all other substances are compared to water.** The value for **q** can be changed to Joules by the conversion factor, 1 calorie = 4.184 Joules; thus, the equation which we will use is:

$$q = (m_{water})(\Delta T)(4.184\ J/g\ °C)$$

To measure specific heat in the laboratory, a **calorimeter** is used. A calorimeter is a well-insulated container used in measuring energy changes. The calorimeter contains water and is insulated to reduce the loss or gain of energy to or from the surroundings. Energy always flows from a substance at a higher temperature to a substance at a lower temperature. The heat gained by the cooler substance equals the heat lost by the warmer substance, if we assume no loss of heat to the air outside the calorimeter.

heat lost by "system" = heat gained by water

Target:

In this experiment, you will determine the specific heat for a given metal. The metal sample will be heated to a high temperature then placed into a coffee cup calorimeter containing a known amount of water. If you can find out how much heat was gained by the water in the calorimeter than you will know how much heat was lost by the metal.

Heat lost by the metal, q_{metal} = - (Heat gained by the water, q_{H2O})

You will be able to solve for the specific heat capacity of the metal (c_{metal}) because everything else in the equation will be measured or known.

Prelaboratory Assignment

Read the **Introduction** and **Procedure** before you begin. Answer the Prelaboratory Questions.

1. Since the specific heat of water is given in units of joules per *gram* degree Celsius why do we measure the volume of water in the calorimeter instead of its mass?
2. A 22.50-g piece of an unknown metal is heated to 100.°C then transferred quickly and without cooling into 100. mL of water at 20.0°C. The final temperature reached by the system is 26.9°C.
   a. Calculate the quantity of heat absorbed by the water. Show all work.
   b. Determine the quantity of heat lost by the piece of metal. Show all work.
   c. Calculate the specific heat of the metal in J/g °C. Show all work.
3. What would be the effect on the value of the specific heat capacity of water if all temperatures were measured in kelvins (K) rather than degrees Celsius (°C)? Explain.

Materials

balance	250-mL beaker (2)	Safety goggles
Tap water	Thermometer	Lab apron
Foam cups, 6 oz (2)	50-mL graduated cylinders	Hot pad or mitt
Metal sample	Hot plate	

Procedure

Calorimeter Apparatus

The calorimeter used in this experiment is made of two white foam polystyrene coffee cups. Foam polystyrene, as you know from experience, is an excellent insulator. Stack two Styrofoam cups, pierce the bottom of the top cup to insert a thermometer. The thermometer should touch the bottom of the inner cup. Make a tight-fitting hole for the thermometer. (See **Figure 1**.)

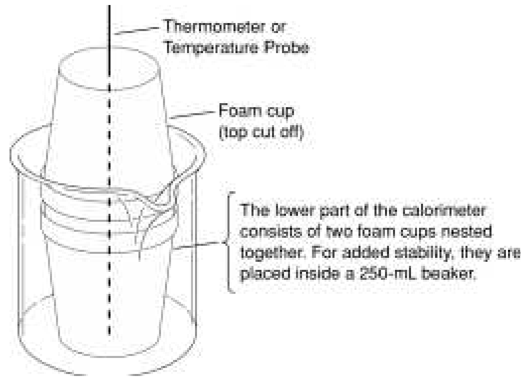

Figure 1
The calorimeter

1. Fill a 250 mL beaker with about 200 ml of water. Place it on your hot plate or heating apparatus and begin heating the water to boiling.
2. Place exactly 50 ml of water in the calorimeter and measure the exact volume. Note and **record the temperature and volume** in your Data Table.
3. Obtain a metal sample. Note and record the mass of the metal sample in your Data Table. Place the metal sample in the boiling water bath for about 3 minutes. This is to ensure that the temperature of the metal is 100°C, the temperature of boiling water. **Note: The metal sample is hot. Use beaker tongs to QUICKLY remove your metal sample from the boiling water.**
4. Quickly and carefully transfer the metal sample at 100°C to the room temperature water in the calorimeter. Quickly place the lid containing the thermometer back on the calorimeter.
5. Note and record the highest temperature reached by the contents of the calorimeter.
6. Repeat the experiment two more times, starting with fresh, cool water in the calorimeter and a dry sample metal.

Data Table:

	Trial 1	Trial 2	Trial 3
Volume of H_2O in your calorimeter			
Mass of H_2O in your calorimeter			
Initial temp of H_2O in your calorimeter			
Final temp of H_2O in your calorimeter			
ΔT of H_2O ($Final_{H2O}$ – $Initial_{H2O}$)			
Mass of metal sample			
Initial temp of metal sample	100 ºC	100 ºC	100 ºC
Final temp of metal sample			
ΔT of metal ($Final_{metal}$ – $Initial_{metal}$)			

Questions and Analysis

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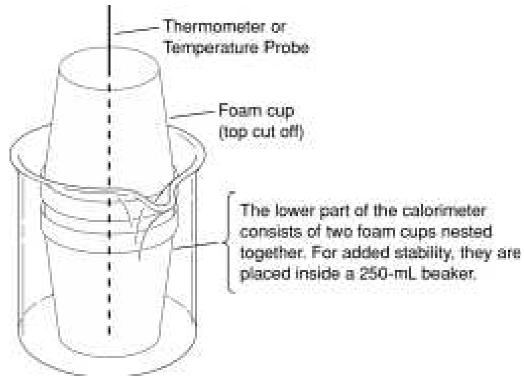

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