16215 HEAT TRANSFER

Purpose:
To introduce the concepts of heat energy and heat transfer by observing the flow of heat between two objects of differing temperatures and to use the heat equation to predict the results.

Required Accessories:

Boiling water
Wood alcohol
Graduated cylinder

Description:

Suppose there are two systems, A and B, that When placed in contact and equilibrium reached, the temperature of system A decreased and the temperature of system B increased. It would be natural to assume that system A lost something and that something flowed into system B. This process is known as heat flow or transfer of heat from A to B.

Heat, as a form of energy is not measured directly, however, we can detect how it effects matter. The energy associated with heat is the vibration of molecules within the material. The more heat a material contains, the faster the molecules in that material are vibrating. The amount of vibration that we detect as Temperature. By measuring temperatures, it is possible for you to investigate the flow and transfer of heat energy from one object to another. In this series of experiments you will investigate the transfer of heat from equal volumes of two identical materials of different temperature, different volumes of two identical materials of different temperature, and finally equal volumes of different materials of different temperature.

A calorie is a unit of heat measurement. One calorie of heat is required to raise one gram of water (1 mL) one degree Celsius. As you might guess, a calorimeter is a “meter” used to investigate heat and its properties. Because you are investigating heating effects with a calorimeter, the calorimeter must keep whatever heat you start with in and any outside heat out. So, a calorimeter is basically a well insulated container. In these experiments, four foam cups with lids (provided) will act as calorimeters. To increase the insulating effect of the cups, you may wish to “double up” the cups on either side of the heat transfer bar. The only path the heat energy can take is through the aluminum transfer bar.

Push the end of each leg of the aluminum bar through the slot in the center of each insulating lid. Insert a thermometer into the remaining slot in each lid. Test the fit of the lids on each calorimeter cup. Fill one cup with 200 mL of room temperature water. Place the insulating lid with the -20 to 50°C thermometer on the top of this cup. Record this temperature. Pour 200ml of boiling water into the remaining cup. Quickly place the remaining insulating lid on this cup. Record the temperature of each cup every 2 minutes for a total of 30 minutes. Plot your data on graph paper with the temperature of both calorimeters placed on the vertical axis and the time on the horizontal axis.

How do you know heat was transferred from one calorimeter to the other? (*The temperature of the hot cup dropped and the temperature of the cool cup increased.)*

In which direction did the heat flow? (*From hot to cold.)* The lines on your graph do not cross although they appear to be getting closer as time increases. If you measured the temperature of each cup for a long enough time, would the two lines eventually cross? (*No)*

Where is the slope of the graph the greatest? (*At the beginning of the experiment.)*

What does this tell you about the rate of heat flow as compared to temperature difference? (*The greater the temperature difference, the greater the rate of heat transfer)*

The heat gained by one calorimeter should equal the heat lost by the other calorimeter. If both calorimeters contain the same amount of water the temperature gain of one should equal the temperature loss of the other.

Did you observe this in your data? And why not?
(*No - heat lost to air and aluminum bar resulting in greater heat loss and less heat gain*.)

How do different volumes of hot and cold water effect the equilibrium temperature? To investigate this question, measure 100 ml of lukewarm water into one of the calorimeter cups. Place the insulating lid over this cup and record the temperature. Place 200 ml of boiling water in the other cup and quickly position the lid over the cup. Use 100°C for the starting temperature of the boiling water. Record the temperature indicated by each thermometer every two minutes for 30 minutes. Plot your data on a graph as you did in the first experiment.

The final temperature of the system can be predicted using the following formulas:

Temperature drop = (amount of cold liquid) / (total amount of liquid) x initial temperature difference

Temperature rise = (amount of warm liquid) / (total amount of liquid) x initial temperature difference

Using these equations, predict the temperature at which the two containers should stabilize. To illustrate this problem using the equation for heat transfer:

$$Q = mc\,(T_f - T_i)$$

where

Q is the heat transferred
m is the mass of the material
c is the heat capacity of the material (water = 1 cal/gram x °C)
T_f is the final temperature of the material
T_i is the initial temperature of the material

For our example, if you started with 200 ml (grams) of 100°C water and the temperature of the water dropped 25 degrees, then the heat transferred is Q = 200 x 25 = 5000 calories lost from hot water. This means that 5000 calories must have been gained by the cooler liquid. Rearranging that heat equation to solve for the final temperature gives:

$$T_f = Q / m + Ti$$

If the 100 ml (grams) of the cooler water started at 20°C and gained 5000 calories, then the final temperature of the cooler water would be:

$$Tf = 5000/100 + 20 = 70°C.$$

Why did the temperature of the cooler water increase more rapidly than in the first experiment? (*Smaller volume of water, therefore less heat is required to raise its temperature.)*

How do your experimental results compare with your calculations? (*Equilibrium temperature on the graph is slightly below calculated value.)*

Can you explain any discrepancy found between your data and your calculations? (*Heat loss to air and heat held in aluminum bar.)*

You may have noticed in the equation for heat transfer that the term "c" represented the heat capacity of a material. The heat capacity for water is 1 calorie/gram°C. However, different materials may have different abilities to store and transfer heat. Consider the following table of heat capacities:

Material	**Heat Capacity - cal / (g x deg C)**
Copper	0.093
Alum.	0.215
Glass	0.201
Water	1.000
Methanol	.0610
Ethanol	0.593

To illustrate the effects of different materials heat capacities, pour 200 mL of room temperature Methanol (wood alcohol) into one calorimeter. Place the insulating lid on the cup and record the alcohol's temperature. Next, pour 200 ml of boiling water into the second container and cover it quickly with the insulating lid. Use 100°C for the initial temperature of the boiling water. Record the temperature every two minutes for a period of 30 minutes. Plot your results on graph paper as you have done for the previous experiments.

How does this graph compare with the graph from your first experiment when you measured the heat flow between two equal volumes of water. What is the expected final temperature?

Use the heat equation to calculate the expected final temperature for this last experiment. Remember, the heat lost by the hot liquid will show up as heat gained by the cool liquid.

How does this result compare with your graph? (*Graph temperature is lower - heat lost to air and aluminum bar.)*

How does this experiment compare to the first experiment using water in both cups? (*Temperature of alcohol rises more rapidly and final temperature is higher.)*

Can you explain the difference? (*The heat capacity for alcohol is less than for water. It takes about 1/3 less heat to raise the temperature of alcohol 1 degree as compared to water.)*

Note:
The insulating foam lids may shrink slightly after being exposed to boiling water for some period of time. If this occurs, it can readily be brought back into shape at the end of an experiment by squeezing the edges between your fingers and gently, but firmly, pulling outward at opposite ends of the disk's diameter. Continue this procedure until the disk is back in shape.

If you need additional disks, they can be purchased separately from The Science Source. Ask for the Heat Transfer (part #1621503).

Time Allocation:

No prior assembly is required for this product. Individual experiment times will vary depending methods of instruction, but normally will not exceed one class period. The Aluminum Bar and the Thermometers should be removed from the lids at the conclusion of the activity to make the apparatus ready for the next time.

Feedback:

If you have a question, a comment, or a
suggestion that would improve this product, you may call our toll free number.