Investigation H3: Conservation of Energy Model Development

Activity H3.1: Can you predict the temperature?

In this activity you will be given samples of water at different temperatures. Your task is to predict what the final temperature of the water will be when you mix the two samples together. Each group in the class will get one of the mixes listed below.

1. **WHAT'S YOUR IDEA?** Predict in advance of carrying out the experiment what the final temperatures of the following mixes of water will be. If you don't think you can guess a temperature, predict in general terms, such as 'more like the warmer water' or 'more like the cooler water'.

   a) equal amounts at equal temperatures
   b) equal amounts of hot and cold water
   c) larger amount of hot water and small amount of cold water
   d) large amount of cold water and small amount of hot water

2. **CARRY OUT THE EXPERIMENT.** Now that you have predicted the final temperatures, you should determine the actual values from carrying out the experiment. The instructions are the same for all the mixes.

   i) Obtain samples of water from your instructor.
   ii) Measure the temperature of each sample.
   iii) Dump the samples together, stir and measure the temperature of the mixture.
   iv) Post your data on the whiteboard for discussion purposes.

3. **MAKING SENSE:** Develop a mathematical rule to enable you to predict the final temperature of mixtures of various amounts of water at various temperatures.

   What evidence can you offer that your rule works?

4. **WHAT'S YOUR IDEA?** From your mixing observations, can you tell which parts of your mixtures gained or lost heat energy? Can you tell if the cooler water gained warmth, or the warm water gained cold?

Activity H3.2: Charting Method for Mixes

1. **MAKING SENSE:** What factors did you find that affected the amount of ice that could be melted by water?

   What factors did you find that affected the final temperature of the mixture of two different temperatures of water?

2. **THE CHARTING METHOD:** Your instructor will illustrate a method of charting the mixtures of water to predict the final temperature of the mixture. This method will take into account the important factors that determine that temperature. After the method has been illustrated, try it on the mixture your group did.

3. **WHAT DID YOU FIND?** Can you predict the final temperature of a mixture of water? Can you use this charting method to develop a way to calculate the final temperature? If so, write it below.

4. **MAKING SENSE:** What generalizations can you make about the number of squares when water is mixed together? What does each square on the chart represent?

Activity H3.3: Specific Heat

In the previous activities you looked at mixing together the same substance. What would happen if the materials mixed together were not the same? In this activity, small cylinders of metal will be heated in boiling water. These pieces of hot metal will then be dropped into cold water, and the final temperature of the mixture measured.

1. **WHAT'S YOUR IDEA?** What is the temperature of the hot metal before you put it into the cool water? How do you know?

2. **MAKE A PREDICTION?** Your instructor will tell you the approximate temperature of the cold water. Using the charting method, predict what the final temperature of the metal and water mixture will be.

3. TRY THE EXPERIMENT. Follow the instructions below.

i) Obtain about 3 cm of water in a foam coffee cup. Measure the mass of the water.
ii) Take the water and your thermometer to the location of the hot metal. Measure the temperature of the water, then immediately drop a sample of metal in the cup. Stir the metal and water gently for about 30 seconds, and then measure the temperature of the water and metal.
iii) Compare the measured temperature to your prediction. What did you find? Why do you think this happened?

Specific Heat: The Water equivalent.

To make the charting model applicable to mixing different substances, a modification must be made. One can do this by inventing the "water equivalent" of the metal, also known as the specific heat. In other words, the specific heat indicates how much hot water (100^{o}C) you would have had to use instead of the hot metal to cause the same observed final temperature. Specific heat is indicated as a multiplicative decimal factor. Its overall meaning turns out to be the amount of heat energy that must be added to 1 gram of a substance to change its temperature by 1^{o} C. By multiplying the actual mass of the metal by its specific heat, then using this 'water equivalent' mass, the charting method or its mathematical representation can be used to predict the final temperature of the metal and water mixture.

Find the specific heat of the metal sample you used in the chart below, then use the method described above to predict what the final temperature of the water and metal mixture should have been. Compare this new prediction to the actual measured value.

Substance	Specific Heat (cal/g ^{o}C)
Aluminum	.215
Copper	.092
Iron	.107
Lead	.031
Zinc	.387
Brass	.092
Glass	.200
Alcohol (ethyl)	.580
Water	1.000

Activity H3.4: Flame Temperatures

Since the temperature of the flame of an alcohol lamp is too high to be measured directly with a thermometer, with your group design a way of using a steel washer with a known specific heat capacity of 0.11 cal/g^{o}C and any other equipment that you have used so far to measure the temperature of the flame.

1. **WHAT IS THE GROUP'S PLAN?**

2. **WHAT DO YOU THINK THE TEMPERATURE OF THE ALCOHOL LAMP FLAME WILL BE?**

3. **CARRY OUT YOU EXPERIMENT AND DETERMINE THE TEMPERATURE OF THE FLAME.** Post your results on the whiteboard for discussion purposes.

Investigation H4: Change of State

Activity H4.1: Freezing and Melting

You will have access to substances that are in the liquid state that you will allow to cool. Place a temperature-measuring device in the test tube containing the hot liquid and monitor the temperature vs time of the substance as it cools. Plot a temperature vs time graph of your results. If you are using a computer sensor to monitor the temperature, your instructor will provide you with instructions on using the software needed to carry out this task.

1. **WHAT'S YOUR IDEA?** Compare your cooling curve with that of other lab groups.

2. **MAKING SENSE.** What was happening as cooling took place?

On your graph, mark the region where the substance was a liquid.

Mark the region where the substance was a solid.

What is going on during the time of the plateau?

What was the temperature during the plateau?

Was heat being removed from the test tube throughout the process? How can your justify your answer?

3. Your personal experience has now been extended to substances that are "freezing" or "melting" but in quite a new fashion. This should cause you to rethink the terms freezing and melting and to be able to describe them in a much broader manner. Record your present understanding of "melting" and "freezing."

4. If ice melts at $0^{o}C$, at what temperature does water freeze? How do you know?

Activity H4.2: Freezing Water

1. **WHAT DO YOU THINK IS THE TEMPERATURE OF ICE?** How do you know?

2. **TRY AN EXPERIMENT:** Prepare a mixture of ice and salt (brine-ice mixture) in a beaker and place a temperature-measuring device inside. Use the mixture as a bath in which you place a small test tube of pure water that also contains a temperature-measuring device. Monitor the temperature of both and describe the system behavior over time. Your instructor will provide you with instructions on using the computer as a temperature-measuring device for this experiment.

3. Lift the newly formed ice in the test tube out into the air and continue to monitor its temperature over time. Record your observations and discuss the meaning of the results.

4. Now what do you say about the temperature of ice?

II. Focus on Science

Focus on Science H3.4: Equilibration Temperatures

When you measure the temperature of something with a thermometer or temperature probe, what is finally measured is the temperature of the probe itself. In order for the probe to represent the temperature of the object, it must have come to temperature equilibrium with that object. In every case this takes time. The first indication of this process probably occurred as you watched the thermometer change its temperature, quickly at first, and then more slowly until the change finally ceased.

When you placed the iron washer in the flame, it too took some time to reach the temperature of the flame. The washer came into equilibrium with the temperature of the flame. When the hot washer was then placed in a water bath to see what sort of energy it gave up in changing from the flame temperature to the water bath final temperature, the washer and the water bath had to come to equilibrium with each other.

The most common temperature, and one that we rarely think of, is room temperature. We do not realize that all objects in the common environment of a room eventually reach a common temperature, called room temperature.

Focus on Science H4.1: Latent Heat of Vaporization and Fusion

Latent heat is a reference to "hidden" heat. An excellent example is an ice cube. An ice cube can be cooled well below its melting temperature. It exhibits a specific heat of 0.5 cal/g^{o}C, half that of water, and can be warmed and cooled without melting as long as its temperature does not rise to its melting temperature. When, through heating, its temperature is raised to its melting temperature, it can acquire heat energy from its surroundings without the ice cube and resulting ice water warming any further. This ability to absorb heat energy without the ice and resulting ice water increasing temperature is evidence that heat energy, which in the case of a piece of metal, would have raised its temperature, is going somewhere but no longer causing a temperature change. Actually it is stored in changes in the structure of the ice as it changes to water.

If one reverses this process and removes heat energy from water, the first energy removal results in a reduction in temperature that ends when it reaches the freezing temperature. Further attempts to reduce its temperature result only in a loss of heat energy from the water, but no accompanying change in temperature.

Equivalent processes are associated with the change of state of water to steam. It takes energy (which is stored in the changed structure of the water that has become steam) to bring about this change. If steam is condensed then this stored or "latent" energy is released.

It takes 80 cal to change 1 g of ice to 1 g of water. It takes 540 cal to change 1 g of water to 1 g of steam. These same amounts of energy are released when the reverse process occurs.

Focus on Science H4.2: Winter Roads and Ice Cream Making

Ice cream could be made in the summer only through extraordinary efforts in the days prior to refrigerators. You have employed the methods used to make ice cream. When an ice and water mixture has salt added to it, it lowers the temperature at which ice melts. As you observed, the temperature of the ice and salt mixture falls below 0ºC. This places the water and salt bath at a temperature lower than the chilled ice cream mixture. As long as the water and ice are below 0ºC, heat energy will be removed from the as yet unfrozen ice cream allowing it to freeze. Mixing (cranking) ensured a rapid cooling of all of the fluid in the can and prevented ice crystals from forming apart from the ice cream.

On winter days where the temperature hovers just below freezing, adding salt to the surface of the ice will lower its melting temperature below the air temperature, thus allowing ice normally at 0ºC to melt on a day that the temperature is below freezing. On extremely cold days salt will no longer help since the air temperature falls below the melting temperature of ice and salt.

Focus on Science H5.1: Energy Storage and Transformation

It is very interesting to follow the changes in the forms of energy from fossil fuels used in the production of electrical energy to the delivery of the electricity to our homes where it is used to run an appliance such as a vacuum cleaner. The great thermal energy within the Sun was presumed to be produced through the process of nuclear fusion. Some of the thermal energy of the Sun changes to light energy at the surface of the Sun and travels to the Earth in the form of sunlight. The sunlight was presumably absorbed by the leaves of plants on the Earth, where through the process of photosynthesis, it was converted to stored chemical energy in the form of organic matter. Through geological processes, the organic matter was changed to coal or other fossil fuels, which in turn are burned at a power plant producing thermal energy. The thermal energy is used to produce steam that expands through a turbine to produce energy of motion that is then converted to electrical energy in large generators. This electrical energy is transmitted by wires to our homes where the electrical energy is finally converted into mechanical energy in the motor of the vacuum cleaner.

III. Homework

Homework H2.2: Hot and Cold

1. Park benches are usually made of wood and not metal. Why?

2. If you are in air at 72^{o}F, it feels warm; if you are in water at 72^{o}F, it feels cold. Explain why. Which of these two environments (the air or the water) have the highest temperature? Explain.

3. How are temperature scales developed? On what basis do they work?

Homework H3.3: Mixtures and Specific Heat

1. What will be the final temperature of a mixture of 50 g of water at 10^{o}C with 100 g of water at 70^{o}C?

2. If you mix 50 g of a metal with 100 g of water at 20^{o}C, what will be the final temperature of the mixture if the specific heat of the metal is 0.1 cal/g ^{o}? The temperature of the metal before mixing is 100^{o}C.

3. If you mix 75 g of a metal with 200 g of water at 22^{o}C, the final temperature of the mixture is 26^{o}C. The temperature of the metal before adding it to the water was 100^{o}C. Determine the specific heat of the metal.

Homework H5.1: Changes in Energy

1. Discuss the changes in the forms of energy during the operation of a yo-yo.

2. Discuss the changes in the forms of energy associated with the hydroelectric production of electrical energy.

3. Select a familiar mechanical toy and discuss the changes in the forms of energy during its operation.

4. Discuss the changes in the forms of energy in the operation of a household furnace.
5. Discuss the changes in the forms of energy in the operation of a refrigerator.

6. Discuss the changes in the forms of energy in the operation of an automobile.