Thermal Energy

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INTRODUCTION

Many teachers are at the forefront in implementation of actions outlined in the Texas Essential Knowledge and Skills (TEKS) through their classroom instruction. Good teachers take on the responsibility for providing opportunities for students to achieve added proficiency through the growing use of computer technology and science curriculum materials. A teaching unit, which blends content and laboratory activities, seems "tailor-made" in helping students to better understand principles of thermal energy.

At a time when society is being transformed by information and communication technologies, many science classrooms are lagging in the application of this technology. The use of technology in classroom laboratories can go a long way in holding student interest, encouraging student creativity, and conveying information. The unit of instruction outlined in this composition stems from an effort to increase the awareness of new way of applying physics in our everyday world through the use of the computer. A computer approach to facilitate learning can pay significant benefits while allowing data to be more readily assessed.

The activities are carefully organized to help teachers with short or long assignments and to encourage each teacher to model the interconnection between physics and mathematics, thereby enhancing existing laboratory exercises with computer technology. Through the use of technology students are able to quickly create visual representations of data. Use of information gained through technology offer opportunities for improvement. The use of technology is the key for ensuring well-informed, highly motivated students.

The proposed curriculum unit *Thermal Energy* will be a laboratory-oriented mini-course for students taking Integrated Physics and Chemistry and/or Physics in high school with emphasis on the use of technology-computer. The unit is designed for seven days.

Everything has thermal energy! Thermal energy, "energy of temperature", is based on movement of molecules. Whether a substance is a gas, a liquid, or a solid, the particles of which it is composed are restless and in motion. This motion is, in general, random. For example, while a car is parked, the air in its tires has no directly observable transitional motion. Nevertheless, the individual molecules are moving, and in their motions are found all possible directions and a wide range of speeds. But these motions are completely disorganized except in two respects: they are confined within a definite space, and the vector sum of the velocities of all the individual molecules is zero.

There may also be internal vibrational or rotational motion of the individual molecules. Whatever the type of the microscopic random motion of the particles, the summation of all the energies constitutes the internal energy, or the thermal energy, of the substance comprised by the particles. Thermal energy of a material is the total kinetic and potential energies of all its particles and dependents on the amount of material. Heat is the thermal energy transferred between objects at different temperatures.

For a given mass of a specific substance, the quantity of thermal energy determines the temperature, and vice versa. Thus, if the temperature of the substance rises, it does so because of an increase in the thermal energy, and any decrease in the thermal energy causes the temperature to fall. (See Figure 1.)

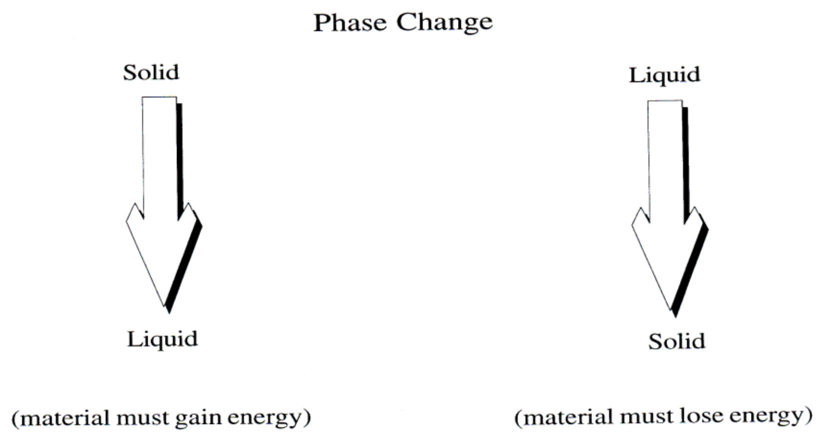

Figure 1

Heat may exist as the thermal energy both before and after transfer, simply flowing from a warmer body to a cooler one. However, the energy may exist initially as microscopic internal energy and after transfer it may be in the form of macroscopic mechanical energy, and the reverse may also occur. Heat is the energy that flows as a result of differences in temperature. The symbol, Q, is for heat and is measured in joules. The heat supplied by warm water, Q, is found by using the equation $Q=mC\Delta T$ where m is the mass and the water in grams, C, is the specific heat of the water (4.18J/g *C). And ΔT is the change in temperature of the water. Using the same equation, the student will compute the heat gained by the cold water and heat gained by the calorimeter cup. A calorimeter is an apparatus designed to prevent the objects placed in it from gaining or losing thermal energy to the surroundings. The conversion of the thermal energy of exploding gasoline to mechanical motion of an automobile is one of many familiar examples of the former process. There is ample evidence of the later process also: primitive peoples and Boy Scouts start fire by friction, a basketball player may get a "floor burn" (literally) as he slides along the floor, a firmly embedded nail is hot immediately after being pulled, etc.

Solar energy can be an important alternative source. What can we do to ensure that energy from the sun is available on cloudy days or at night? Storage of solar energy is one of the problems that must be solved before solar energy can be used on a large scale. Various materials can be used to absorb and store thermal energy from the sun and other sources. It should come as no surprise that some substances are better than others for storing energy.

The students will have opportunities to discover relationships among facts and concepts relating to thermal energy. While the students may not remember facts, they may respond well to activities, which require the use of facts and ideas. This curriculum unit will provide visual applications of thermal energy to support the teaching of thermal energy. A variety of resource material will be used: for example, laboratory material, textbooks, related material, and a guest speaker. Students will be engaged in innovative activities, with technology at the center of the unit for two weeks.

Software programs on CD-ROMs allow students to learn about energy related topics through text, audio, and video images, which are available commercially. They should be used in schools to help ensure that all students are knowledgeable about the application of thermal energy, especially as it is being related to technology for the future.

Students will perform the following experiments.

- Investigate temperature changes by using the temperature probe which will be connected to the computer monitor, and
- Demonstrate what happens when naphthalene is heated, then cooled.
- In another activity, "Canned Sunshine" students will use common materials to construct a method of storing thermal energy. (See Figure 2.)

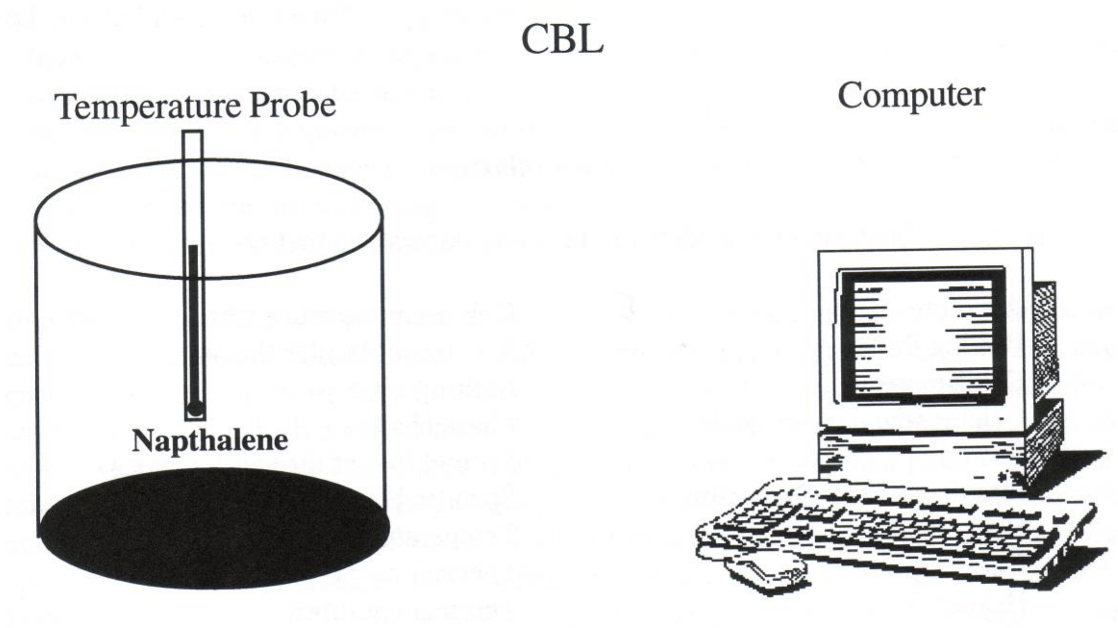

Figure 2

In each laboratory the temperature probe will be used to monitor and collect data.

Using the Science Workshop interface and a PASCO Temperature Sensor, students will create a temperature calibration file. Students will use analog probes to send a voltage signal to the Science Workshop Interface. The Science Workshop Program includes a calibration feature, which converts the voltage signal to a temperature, force, pH, and etc. The software uses a linear conversion routine, which requires two data points to define a straight line. One criterion for designing a sensor is that its voltage output is linear with respect to the quantity being measured. The Temperature Sensor produces a voltage that is proportional to temperature. The default calibration is 110.000° C = 1.100v and -10.000°C = 0.100v. Boiling water and ice have known temperatures, which can be used for calibration purposes.

Opportunities will be established to provide a link between other topics and this unit. A bibliography will be included.

GOALS

- The effects of thermal energy on matter are explored using kinetic theory to explain the basic scientific principles behind many observations such as melting ice, boiling liquids, and freezing water.
- The difference between heat and temperature is firmly established. The relationships among thermal energy, heat, and temperature are also explored. The ability of different substances to absorb thermal energy is studied experimentally as is the energy released or absorbed during a change of state.
- Thermal energy that is transferred from one quantity of matter to another because of a difference in temperature. Avoid using the term “heat energy.”

OBJECTIVES

1. Distinguish potential and kinetic energy, and predict the relative values of each, and define thermal energy.
2. Define temperature and heat.
3. Describe the relationships among temperature, heat, and thermal energy.
4. Compare heat and work.
5. Demonstrate that work can produce a change in temperature.
6. Calculate and measure changes in thermal energy.
7. Define calorimeter.
8. Make calorimetric calculations for heat lost and gained.

Vocabulary

Terms to help students to read and understand text content.

Absolute Zero	Kelvin temperature scale
Boiling Point	Kinetic-molecular theory
Calorimeter	Melting ping
Celsius temperature scale	Phase change
Entropy	Second low of thermodynamics
First law of thermodynamics	Specific heat

Heat
Heat engine
Heat of fusion
Heat of vaporization

Temperature
Thermal energy
Thermal equilibrium

Formulas

$Q=\Delta T x m x C_p$
$\Delta T = T_{final} - T_{initial}$
or
$\Delta T = T_f - T_i$
$Q = (T_f - T_f) \times m \times C_p$

DAY ONE

I. Have students recall the definition of energy and list and discuss situations that indicate is a kind of energy.

Vocabulary
Temperature
Energy
Thermal energy
Heat
Potential energy

II. Using Thermal Energy (New Refrigerator)
Using Thermal Energy (Events Chain Map)

Using Thermal Energy

New Refrigerators

The refrigerator may have to be reinvented in the coming years. The substances now being used to produce refrigeration, called refrigerants, must be replaced. Damage to Earth's ozone layer is one of the reasons for these needed changes.

A gaseous refrigerant is used to remove heat from the inside of the refrigerator. A refrigerant should boil at a temperature somewhat lower than the required freezer temperature. Only a few chemicals boil within the required temperature range and are also nontoxic, nonflammable and noncorrosive. Chloro-flourcarbons (CFCs) are chemicals that meet these requirements. Only a small amount of CFCs is required for each refrigerator or air conditioner. CFCs are also used in aerosol spray cans.

Recently, it was discovered that CFCs can destroy Earth's ozone layer. Ozone helps to screen out cancer-causing ultraviolet. Each refrigerator contains only as small amount of CFCs. However, the total amount released from disposed refrigerators, leaks in appliances, and other sources such as air conditioners and spray cans alarm some environmental groups. In 1987, a treaty was signed in Montreal by most of the industrial nations. This treaty proposed that the use of CFCs be reduced by 50 percent by 1998. The treaty is being renegotiated to completely phase out all CFC use by the year 2000.

New refrigerants will have to be developed to meet that goal. Computer simulations show that the next generation of refrigerators could use less than half the energy of today's most efficient models. More testing and development is needed to determine practical CFC replacements. Some people think that methods to capture and recycle CFCs would be cheaper and less hazardous than trying to use CFC replacements.

Applying Problem Solving Skills

1. What perspective would a refrigerator manufacturing company have with respect to banning CFCs?

____
____
____
____

2. Suppose a new refrigerant was found that had most of the characteristics of CFCs, and did not harm the ozone layer, but was more flammable. Should this refrigerant be used? Why or why not?

____
____
____
____

DAY TWO

I. Have students perform "RXN in a Bag". Students will relate the following: temperature, thermal energy, and heat to the rxn occurring in their Ziploc bag.

II. The Calorimeter
Mark several problems on the transparency to help students understand calorimeter calculations.

$$Q = \text{^}T \times m \times C_p$$
$$Q = (T_i - T_f) \times mx\ C_p$$
$$Q = (T_f - T_i) \times mx\ C_p$$

III. Heat and Phase Changes
Heat Calculations

Heat and Phase Changes

During the phase change, the temperature remains the same. For these calculations, we use the following formulas.

For freezing and melting, heat = (mass in grams) (heat of fusion) For boiling and condensation, heat = (mass in grams) (heat of vaporization) The heat of fusion of water = 340 J/g The heat of vaporization of water = 2,300 J/g

Solve the following problems.

1.	How many joules of heat are necessary to melt 500 g of ice at its freezing point?	Answer:____________
2.	How many kilojoules is this?	Answer:____________
3.	How much heat is necessary to vaporize 500 g of water at its boiling point?	Answer:____________
4.	If 5,100 joules of heat are given off when a sample of water freezes, what is the mass of the water?	Answer:____________
5.	If 57,500 joules of heat are given off when a sample of steam condenses, what is the mass of the steam?	Answer:____________

Heat Calculations

Heat is measured in units of joules or calories. The amount of heat given off or absorbed can be calculated by the following formula.

$\Delta Q = m \times \Delta T \times C$ heat = (mass in grams) (temperature change) (specific heat) The specific heat of water = 1.0 cal/g C° or 4.2 joules/g C°

Solve the following problems.

1.	How many calories are absorbed by a pot of water with a mass of 500 g in order to raise the temperature from 20° C to 30° C?	Answer:____________
2.	How many joules would be absorbed for the water in Problem 1?	Answer:____________
3.	If the specific heat of Iron = 0.46 J/g C°, how much heat is needed to warm 50 g of Iron from 20° C to 100° C?	Answer:____________
4.	If it takes 105 calories to warm 100 g of aluminum from 20° C to 25° C, what is the specific heat of aluminum?	Answer:____________
5.	If it takes 31,500 joules of heat to warm 750 g of water, what was the temperature change?	Answer:____________

DAY THREE

Students will create a temperature calibration file.

T02 Temperature Calibration (Temperature Sensor)

Purpose

In this activity you will create a temperature calibration file using the Science Workshop interface and a PASCO Temperature Sensor.

Theory

All analog probes send a voltage signal to the Science Workshop interface. The Science Workshop program includes a calibration feature which converts the voltage signal to a temperature, force, pH, etc. The software uses a linear conversion routine which requires two data points to define a straight line. One criteria for designing a sensor is that its voltage output is linear with respect to the quantity being measured. The Temperature Sensor produces a voltage that is proportional to temperature (10mV = 1.-0°C= 1.100V and -10.000°C = -0.100V. Boiling water and ice water have known temperatures which can be used for calibration purposes.

Equipment Needed

Computer and Science Workshop Interface
Temperature Sensor
2.250 mL beakers
hot plate
ice water

Procedure

Setup:

1. Connect the interface to the computer, turn on the interface, and turn on the computer.
2. Connect the temperature sensor to Analog Channel A on the interface.
3. Prepare the computer to record data. Go to the Experiment Library and open the Science Workshop file titled as shown;

Macintosh	Windows
T02 Temperature Calibration	T02_TCAL.SWS

Double click on the icon or name of the document. The document will open with one Table and one Digits display. (Note: To make a display active, click on its window or select the name of the display from the list at the end of the Display menu.)

DAY FOUR

"Using Thermal Energy" Problem Solving Activity (Food Energy)
"Using Thermal Energy" Science Integration Activity (Asbestos)
Laboratory Activity "Canned Sunshine"

Food Energy

Food energy is measured in Calories. The Calorie is defined as the amount of heat required to raise the temperature of 1 kg of water 1°C. A Calorie equals 1 kilocalorie (kcal) or 4.184 kilojoules (kJ). The following table lists the approximate amount of energy used in various exercises. Energy used is expressed in kcal/kg/h.

Table 4.1

Activity	Energy Used (kcal/kg/h)
Lying down or sleeping	1.2
Sitting	1.5
Standing	2.1
Light housework	2.6
Walking 2.5 mph	3.1
Bicycling 2.5 mph	3.1
Bowling	4.0
Walking 4.0 mph	4.5
Volleyball	5.1
Tennis	6.2
Bicycling 13 mph	9.7
Running 10 mph	13.2

1. Determine your mass in kilogram. Multiply this figure by the figures for each exercise to obtain the amount of energy you would use in an hour. For example, a 60-kg student playing volleyball would use 60 kg x 5.1 kcal/kg/h = 306 kcal/h.

   ____

2. Using this table, estimate your own daily energy expenditure. List your activities for a 24-hour period. Calculate the kilocalories expended. (Estimate the energy expenditures for activities not listed in the table.)

   ____

3. You eat a pint of ice-cream (514 kcal) with chocolate topping (125 kcal). Every 0.45 kg of body fat contains 4000 kcal of energy. Assume that your regular diet (without the ice cream) just maintains your current body mass.
   a. How long will it take to burn it off if you are just sitting?
   b. How many hours of tennis will it take to burn it off?
   c. How much mass will you gain from the ice cream and topping if you do not exercise?

Asbestos

Asbestos is a fibrous silicate mineral mined from rocks. It is strong, noncombustible, and can withstand heat, cold, and moisture. Because of these properties, asbestos has been used as an insulating and fireproofing agent in furnace ductwork, heating pipe insulation, shingles for roofing, siding, flooring, stove mates and barbecue mitts.

Asbestos was once regarded as a magic mineral for its insulating and fireproofing properties. However, the Environmental Protection Agency (EPA) restricted its use in 1973 when it was found to scar the lungs, cause cancer, and influence other diseases. This was after millions of metric tons of asbestos had been sprayed on girders or mixed into tiles at a cost of $2.75 per square meter. Now, people are spending 100 times that amount per square meter to remove it, cover it with a sealant, or enclose it. It is estimated that the cost to clean up asbestos could run over $100 billion over the next 30 years.

Not all asbestos-containing products are unsafe. Products in good condition, with the fibers locked in, are not a problem. Asbestos materials that are loose and crumbly release tiny fibers into the air. This condition is called friability. If inhaled, these fibers can become lodged in the lungs. Ten to forty years later, they can cause lung scarring or cancer of the lungs, larynx, stomach, or lining of the lungs.

In most cases, asbestos is not a health threat. Large doses cause the most problems. *If* you suspect friable asbestos in your home, you can hire an asbestos consultant. A list of qualified consultants is available from the EPA office nearest your home.

1. Where in your home is asbestos found?

   ____
   ____

2. If there is asbestos in your school, ask your principal what precautions are being taken to minimize its hazard.

   ____
   ____

3. If asbestos needs to be removed from your school, ask your principal what precautions are taken to do it safely.

   ____
   ____
   ____

Canned Sunshine

Solar energy can be an important alternative energy source. But what can we do to ensure that energy from the sun is available on cloudy days or at night? Storage of solar energy is one of the problems that must be solved before solar energy can be used on a large scale. Various materials can be used to absorb and store thermal energy from the sun and other sources. It should come as no surprise that some substances are better than others for storing energy.

Getting Started

In this activity, you will construct storage tanks for thermal energy. You will compare the ability of gravel and water to absorb and release heat. CAUTION: *Be careful with the warmed materials to avoid burns.*

Hypothesizing

Read through the following procedures. Form a hypothesis about which material is the best for storage of thermal energy. Will this material warm up faster or slower than the other material warms up?

Try It!

You will need:

- beaker tongs or pliers
- hot plate
- 2 small coffee cans
- colored pencils
- graph paper
- 2 thermometers
- gravel
- water
- stopwatch or watch with second hand

1. Use the data table like the one below to record your observations.
2. Pour water into one can until it is half full an set it on the hot plate. Measure the temperature of the water near the bottom and also near the top. Record these temperatures in the table.
3. Turn the hot plate on high and allow it to heat for two minutes. Then, measure the temperature of the water near the bottom and the top. Continue to take these measurements every minute for 15 minutes. Record these temperatures in the table.
4. Carefully remove the can from the hot plate. Turn the hot plate off.
5. In a similar manner, find out the pattern of cooling for the water.
6. Place gravel in the second can until it is half full. Place this can on the hot plate. Measure the temperature near the bottom and top of the gravel. CAUTION: *Gently place the thermometers into the gravel; do not force them.*
7. Repeat steps 3-5 for the gravel.
8. Construct a heating graph and a cooling graph of Temperature versus Time for each material used. Use different colored pencils for each data line.

Table 4.2

Time (min)	Temperature (°C)							
	Heating Water		Heating Gravel		Cooling Water		Cooling Gravel	
	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom
Start								

Summing Up, Sharing Results

Which material heated more rapidly? Which cooled more rapidly? How do you know? Which material would you choose to store energy in a solar collector? Why? Was your hypothesis supported by your observations?

Going Further
Use your results and your knowledge of convection currents to explain why the breeze along shorelines usually blow from water to land during a sunny day and from land to water at night.

DAY FIVE

Lab: Ice Cream (Warm-up or Closure)/Mini-Lab

Students will determine the melting rate (ice cream).
Step 1. Have the student place an ice-cold teaspoon on top of the scoop of ice cream.
Step 2. Have the student place a hot spoon on the scoop of ice cream.
Step 3. Have the student place two hot spoons on the scoop of ice cream.

Questions

1. Which spoon(s) cause the ice cream to change?
2. Where does this energy come from?

Warm-up

1. How does a calorimeter measure a change in thermal energy?
2. Can work increase temperature and thermal energy? Explain.

Using Thermal Energy Critical Thinking Skills (Energy: Is the Oil Age Ending?)

“Ice Cream” Warm-up Activities

What would happen if you used a wooden spoon? Thermal energy would not be conducted through the spoon, and the end not in contact with the heat source would remain cool. What if the spoons were bent? It still would conduct heat.

Part of the spoon is heated by contact with the hot water:

(a) Heat is transferred through the metal spoon, particle by particle, until the entire spoon is hot.
(b) What would happen if you used a wooden spoon? What if the spoon was bent?

Student Text Question

Why do you think cooking pots are made of metal?
Metals are good conductors of thermal energy.
What are the handles usually made out of?
Plastic or wood (Poor thermal energy conductors).

Energy

Is the Oil Age Ending?

When Iraq’s military forces invaded Kuwait in August, 1990, many Americans began to question the Unites States’ dependence on Middle Eastern oil. Crude oil provides 39 percent of the world’s energy sources. Coal, the second largest energy source with 28 percent, and natural gas with 21 percent, will not be able to replace oil as the dominant fuel. Oil has the advantage over coal and natural gas as the fuel for transportation. During the late 1980s, U.S. oil production decreased while consumption increased. What steps should the United States take to reduce its crude oil dependency? The following is a list of items that may be considered in making and energy policy.

1. Re-examine transportation. Cars and trucks use as much oil each day as we import each day. Three measures could reduce that demand. First, use natural gas as a fuel for fleets of cars and trucks. This would be an advantage to the environment because natural gas is a cleaner burning fuel. The problem is that refueling sites are limited. Second, vehicle gas mileage should be improved. A move to smaller, more fuel-efficient cars would decrease oil demand. Third, place a tax on gasoline to encourage conservation.
2. Explore for new energy sources. Some areas are off-limits for exploration in order to prevent environmental damage. Safer methods for exploration and drilling should be found. This would allow use of our domestic l-bearing reservoirs and protect the environment.

3. Increase research into alternative energy sources. Countries such as Sweden, France, Germany, and Japan make more use of nuclear power than the United States does. Nuclear power plant design has been improved. A safer method of disposing of nuclear waste or reducing its radioactive half-life should be researched. Other sources such as solar, wind, geothermal, and hydroelectric power should be explored.

Oil may not be relied upon as the world's primary energy source in the future. Just as oil replaced coal and coal replaced wood as the primary energy source years ago, a new energy source may rise and end *The Age of Oil* in the years to come.

Using Critical Think Skills

1. What could result if oil companies decide to drill for more crude oil from deposits below the ocean?

   ____

   ____

2. What could you or your family do to reduce oil use?

   ____

   ____

3. What do you think will happen when oil, coal, and natural gas reserves are used up?

   ____

   ____

DAY SIX

Laboratory: Conserving Thermal Energy
Student will use the calorimeter to observe the conservation of thermal energy during heat transfer.

Conserving Energy

Purpose

Use the law of conservation of energy to calculate the specific heat of a metal.

Concept and Skill Check

One of several physical properties of a substance is the amount of energy that it will absorb per unit mass. This property is called specific heat, C_s. The specific heat of a material is the amount of energy, measured in joules, needed to raise the temperature of one kilogram of the material one Celsius degree (Kelvin).

A calorimeter is a device that can be used in the laboratory to measure the specific heat of a substance. The polystyrene cup, used as a calorimeter, insulates the water-metal system from the environment, while absorbing a negligible amount of heat. Since energy always flows from a hotter object to a cooler one the total energy of a closed, isolated system always remains constant, the heat energy, Q, lost by one part of the system is gained by the other:

$$Q_{\text{lost by the metal}} = Q_{\text{gained by the water}}$$

In this experiment, you will determine the specific heat of two different metals. The metal is heated to a known temperature and placed in the calorimeter containing a known mass of water at a measured temperature. The final temperature of the water and material in the calorimeter is then measured. Given the specific heat of water (4180J/kg ·K) and the temperature change of the water, you can calculate the heat gained by the water (heat lost by the metal) as follows:

$$Q_{\text{gained by the water}} = (m_{\text{water}})\,(\Delta T_{\text{water}})\,(4180\ \text{J/kg}\cdot\text{K})$$

Since the heat lost by the metal is found by:

$$Q_{\text{lost by metal}} = (m_{\text{metal}})\,(\Delta T_{\text{metal}})\,(C_{\text{metal}}),$$

the specific heat of the metal can be calculated as follows:

$$C_{\text{metal}} = \frac{Q_{\text{gained by the water}}}{(m_{\text{metal}})\,(\Delta T_{\text{metal}})}$$

Materials

String	hot plate (or burner with ringstand, ring, and wire screen)	balance
safety goggles 250-ML beaker polystyrene cup	tap water thermometer	specific heat set (brass, aluminum, iron, lead, copper, etc.)

Procedure

1. Safety goggles must be worn for this laboratory activity. CAUTION: *Be careful when handling hot glassware, metals, or hot water.* Fill a 250-mL beaker about half full of water. Place the beaker of water on a hot plate (or a ring stand with a wire screen) and begin heating it.
2. While waiting for the water the boil, measure the record in Table 6.1 the mass of the metals you are using and the mass of the polystyrene cup.
3. Attach a 30-cm piece of string to each metal sample. Lower one of the metal samples, by the string, into the boiling water. Leave the metal in the boiling water for at least five minutes.
4. Fill the polystyrene cup half full of room temperature water. Measure and record in Table 6.1 the total mass of the water and the cup.

5. Measure and record in Table 6.1 the temperature of the room temperature water in the polystyrene cup and the boiling water in the beaker. The temperature of the boiling water is also the temperature of the hot metal.
6. Carefully remove the metal from the boiling water and quickly lower it into the room temperature water in the polystyrene cup.
7. Gently stir the water in the polystyrene cup for several minutes with the thermometer. CAUTION: *Thermometers are easily broken. If you are using a mercury thermometer and it breaks, notify your teacher immediately. Mercury is a poisonous liquid and vapor.* When the water reaches a constant temperature, record this value in Table 6.1 as the final temperature of the system.
8. Remove the metal sample and rep Steps 3 through 7 with another metal sample.

Observations and Data

Table 6.1

	Trial 1	Trial 2
Type of metal		
Mass of calorimeter cup (kg)		
Mass of calorimeter cup and water (kg)		
Mass of metal (kg)		
Initial temperature of room temperature water (°C)		
Temperature of hot metal (°C)		
Final temperature of metal and water (°C)		

Table 6.2

	Trial 1	Trial 2
Mass of room temperature water (kg)		
ΔT metal (°C)		
ΔT room temperature water(°C)		

Analysis

1. For each trial, calculate the mass of the room temperature water, the change in temperature of each metal, and the change in temperature of the water in the polystyrene cup. Record these values in Table 6.2.
2. For each trial, calculate the heat gained by the water (heat lost by the metal).
3. For each trial, calculate the specific heat of the metal. For each metal sample, use the value for heat gained by the water that you calculated in Question 2.
4. For each trial, use the values for specific heat of substances found in Table C:1 of Appendix C to calculate the relative error between your value for specific heat and the accepted value for the metal sample.
5. If you had some discrepancies in your values for specific heat of the metal samples, suggest possible sources of uncertainty in your measurements that may have contributed to the difference.

Application

The specific heat of a material can be used to identify it. For example, a 100.0-g sample of a substance is heated to 100.0 °C and placed in to a calorimeter cup (having a negligible amount of heat absorption) containing 150.0 g of water at 25°C. The sample raises the temperature of the water to 32.1°C. Use the values in Table C:1 in the Appendix, to identify the substance.

Extension

Obtain a sample of an unknown metal from your teacher. Use the procedure described in this laboratory activity to identify it by the value of its specific heat.

DAY SEVEN

Heat of Fusion of Ice

In a solid, the molecules are held more or less rigidly within a crystalline structure by their mutual attractions. If the solid is to change state and become a liquid, its molecules must absorb energy. This energy is used to do work and increase the separation of molecules. Thus, the cohesive forces between the molecules become weaker. As the molecules gain enough freedom to slide over one another, the solid becomes the free-flowing liquid.

In general, as solids absorb energy, distances between molecules increase. The molecules gain potential energy in relation to one another in much the same manner as a spring gains energy when it is stretched. Thus, the energy absorbed by a solid when melting is reflected as increased molecular potential energy rather than increased molecular kinetic energy. Therefore, the energy absorbed does not result in a temperature rise as the solid changes to a liquid. The quantity of energy absorbed by each gram of a solid in becoming a liquid is called the heat of fusing of the substance. Each substance has a unique heat of fusion.

Objective

During this investigation you will use the law of conservation of energy as a means of measuring the heat of fusion of solid (ice).

Procedure

1. Remove the calorimeter cup and determine its mass. Record this value in Table 7.1.
2. Warm some water in the beaker to about 40°C. Add warm water to the calorimeter cup until it is half full. Measure and record the mass of the cup plus warm water.

3. From the measurements of Steps 1 and 2, calculate the mass of the water. Record all masses in Table 7.1.
4. Place the cup back in the calorimeter jacket and cover it. Measure the temperature of the water. Record this value in Table 7.1.
5. Select two or three medium-sized pieces of ice and wipe them dry. Carefully place the ice in the calorimeter cup. Replace the cover at once. Insert the thermometer and stir gently. As soon as the ice has melted completely and the new volume of water has reached a steady temperature, record this temperature as the final temperature of the mixture.
6. Remove the cup. Determine the mass of the cup plus water and ice. Calculate and record the mass of ice.
7. If time permits, repeat the experiment.

Data and Calculations

Table 7.1

	Trial 1	Trial 2
Mass of calorimeter cup (g)		
Mass of cup plus cool water (g)		
Initial temperature of cup and warm water (°C)		
Temperature of ice when melted		
Final temperature of cup (°C)		
Mass of cup plus water and ice (g)		
		Calculations
Mass of warm water (g)		
Mass of ice (g)		
ΔT warm water and cup (C°)		
ΔT ice water (C°)		

Interpretation

1. Calculate the energy lost by warm water and the warm calorimeter cup.
2. The ice absorbs energy in changing to liquid. It is then water at O°C. Calculate the energy absorbed by the ice water in changing its temperature from O°C to the final temperature of the mixture.
3. The difference between the energy lost by the warm water and the cup (Question 1) and the energy used by the water formed from the ice to raise its temperature to the final temperature (Question 2) must be the energy absorbed by the ice to change state. Calculate the energy used for this purpose.
4. Divide the energy absorbed by all the ice during the change in state by the mass of the ice. This gives the energy per gram needed to effect the change in state of ice.
5. By what percent does your value for Question 4 differ from 334 J/g? Suggest reasons for this difference.

DAY EIGHT

The Specific Heat of a Metal

The specific heat of a substance is the amount of thermal energy that must be added to raise the temperature of a unit mass of the substance through 1 C°.

Objective

During this investigation you will employ the law of conservation of energy as a means of measuring the specific heat of a metal.

Procedure

1. Record all measurements in Table 8.1. Fill the boiler or breaker about half full of water and heat it.
2. While waiting of the water to boil, measure and record the mass of the calorimeter cup. Fill the cup about half full of cool water. Calculate the mass of the cool water by subtracting the mass of the cup from the mass of cup plus water. Put the cup in the calorimeter jacket and cover it.
3. Measure the mass of the piece of metal you are using. Using string, lower the metal mass into the boiling water. Let the metal remain in the boiling water for about 5 minutes.
4. Measure and record the temperature of the cool water and cup.
5. Measure and record the temperature of the boiling water. This will also be the temperature of the metal you will place in the boiling water.
6. Remove the metal from the boiler and quickly lower it into the cold water in the calorimeter cup. Replace the cover at once. Stir gently with the thermometer. When the water reaches a constant temperature, record this temperature as the final temperature of the system.
7. Determine the change in temperature of the metal (ΔT_m) and the change in the temperature of the cool water and cup (ΔT_{cw}).
8. If time permits, repeat the experiment.

Data and Calculations

Table 8.1

	Trial 1	Trial 2
Specific heat of calorimeter J/g°C		
Mass of calorimeter cup (g)		
Mass of cup plus cool water (g)		
Mass of metal (g)		
Initial temperature of cup and cool water (°C)		
Temperature of hot metal (°C)		
Final temperature of system (°C)		
		Calculations

	Trial 1	Trial 2
Mass of cool water (g)		
ΔT metal (C°)		
ΔT cool water and cup (C°)		

Interpretation

1. Calculate the thermal energy gained by the water and the cup by using the expression.

$$Q = (m_w C_{cw} \Delta T_w) + (m_c C_{cw} \Delta T_c)$$

2. The thermal energy gained by the water and cup must have come from hot metal. Therefore, Q is equal to the heat given up by the metal.

$$Q = (m_m C_m \Delta T_m)$$

   Substitute your measured values of Q, m_m, and ΔT_m and calculate the specific heat of the metal.

3. Using Table C: 1 of Appendix C, calculate the percent error between your value for Q and the published value. If you repeated the experiment, use the average value for Q in your calculations.

   If your value does not agree exactly with the published value, suggest possible sources of uncertainty in your measurements.

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4. It is not likely that the temperature of your boiling water was exactly 100°C. Can you suggest several factors that would affect the boiling point of water?

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Extensions

1. Repeat the investigation using a different metal.
2. Calculate the uncertainty in your results. Check Table C: 1 of Appendix C to see if your results agrees with the published results within your range of experimental uncertainty.

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This collection of exercises is used to test the students' abilities to apply thinking skills to situations related to concepts presented in the textbook. The exercise "Using Thermal Energy" will be used.

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