UNIT

4 Energy Transfer in Natural Systems

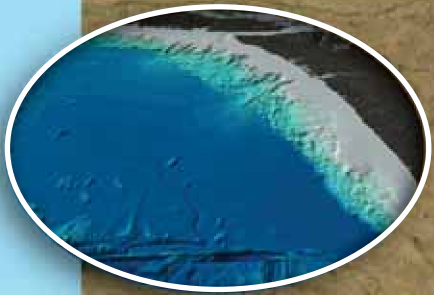
This computer-generated view of the Pacific coast of North America shows a chain of volcanoes, known as the Cascade Range. The "young" volcanoes formed millions of years ago, when massive forces pushed together large plates of rock, releasing magma. Hovering above Earth's surface, you can see the blue sliver of the atmosphere. The atmosphere took form about 4 billion years ago, as ancient volcanoes similar to those in the Cascade Range, released gases trapped within the newly formed Earth.

Key Ideas

10 The kinetic molecular theory explains the transfer of thermal energy.

11 Climate change occurs through natural processes and human activities.

12 Thermal energy transfer drives plate tectonics.



Getting Started

Astronauts on the space shuttle have said that looking through Earth's atmosphere from space is like looking through the glass of an aquarium. Everything necessary for life lies beneath a "thin blue line." For Earth, that thin blue line separates our life-giving atmosphere from the cold, dark vacuum of space. This photograph was taken in 1991, a few days after the volcano Mount Pinatubo erupted in the Philippines, sending dust, ash, and gas 30 km into the atmosphere. As seen from space, residue from the eruption forms a fuzzy brown layer with finger-like shapes that reach into the sunset. The effects of the volcanic eruption could be seen and felt for months. Even in British Columbia, on the other side of the Pacific from Mount Pinatubo, sunsets looked dark crimson. Global temperatures dropped an average of 0.5°C. This eruption was relatively minor, however, compared to some others in Earth's past.

Human activities also greatly affected the atmosphere around the time of Mount Pinatubo's eruption. There was a brown haze on the horizon, made up of smog from the east coast of North America, dense mist from Persian Gulf oil wells that were set on fire during wartime, and the smoke of grass fires set by farmers in the southern hemisphere. These activities affected not only the atmosphere's composition but also the transfer of thermal energy in the atmosphere.

Natural forces on Earth and in the atmosphere are closely linked—not only to each other but also to human activities. In this unit, you will explore the different ways that thermal energy is transferred above and below Earth's surface. You will examine how both natural forces and human activities affect everything that lies below the "thin blue line."

internet connect

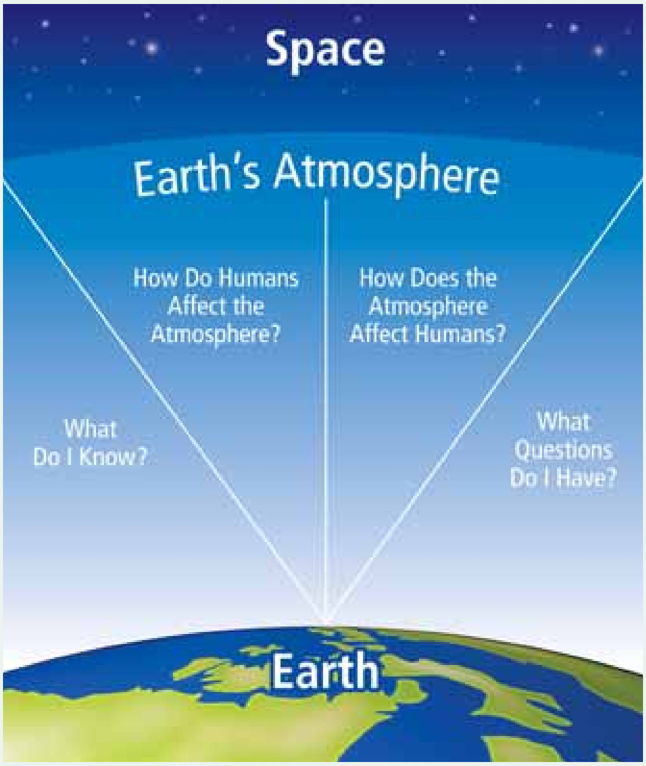
Visit **www.bcscience10.ca** to find out more about the worldwide transfer of matter and thermal energy by Earth's atmosphere.

How Well Do You Know Your Atmosphere? Find Out ACTIVITY

It is easy to take the atmosphere for granted. However, just about every living thing on Earth owes its existence to this narrow layer of gases that separates our world from outer space. How much do you already know about Earth's atmosphere? In this activity, you will work in small groups to brainstorm what you know about the atmosphere, how it affects us, how we affect it, and what you would like to learn about it. As you work through this unit, you may refer back to your notes on this activity to help you organize your thoughts about what you are learning.

Materials

- chart paper
- felt pens or pencil crayons
- stopwatch



What to Do

1. Working in pairs or as a small group, use the chart paper to create a graphic organizer like the one shown here. Under the heading "Earth's Atmosphere," use four subheads:
   - What Do I Know?
   - How Does the Atmosphere Affect Humans?
   - How Do Humans Affect the Atmosphere?
   - What Questions Do I Have?
2. Have a group member set the stopwatch for 5 min. For the first subhead, brainstorm and record as many items as possible in 5 min. Repeat for each of the other three subheads.

What Did You Find Out?

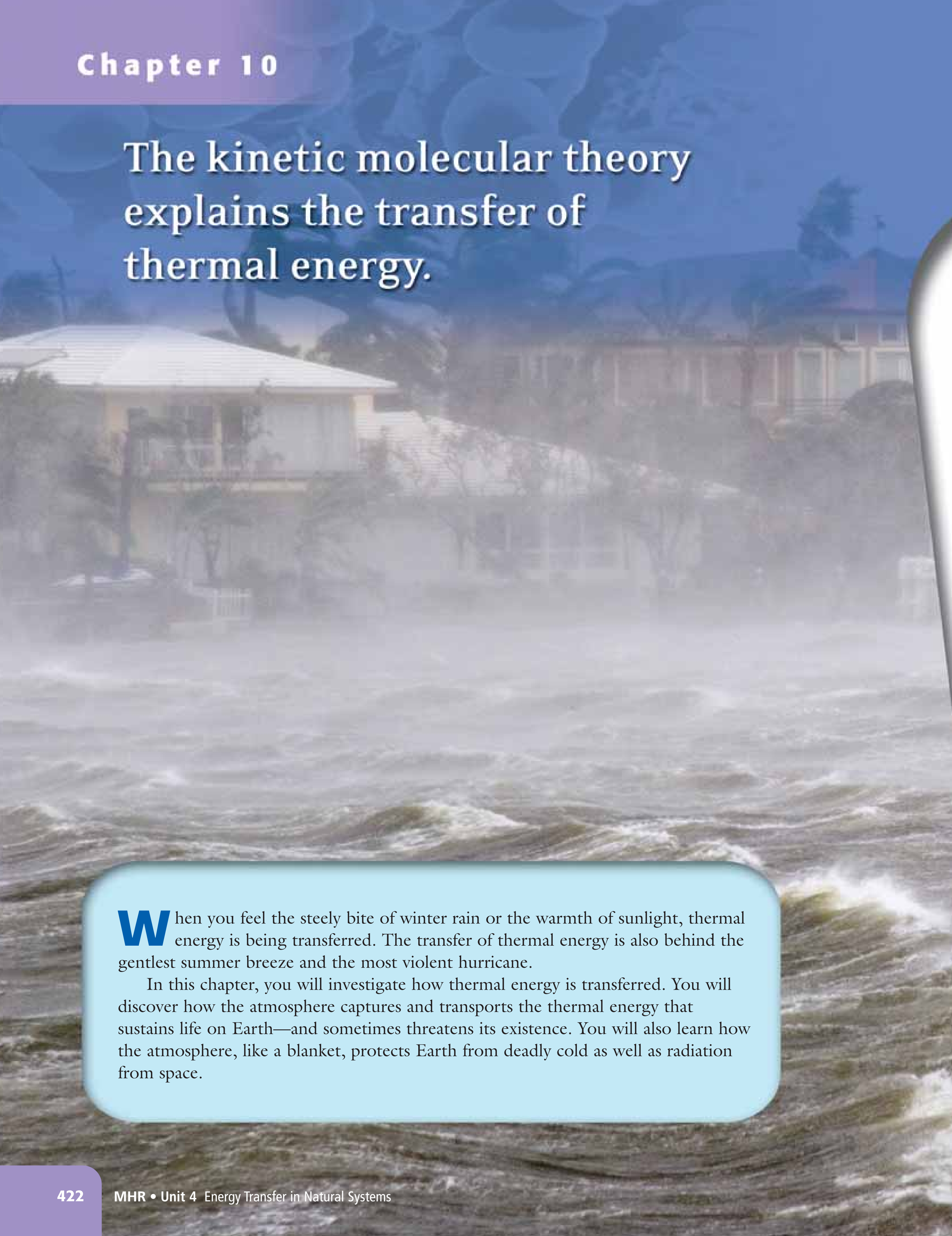
1. Compare your graphic organizer to another group's. Note which items were similar and which were different. Where appropriate, make additions or changes to your graphic organizer.
2. Copy your group's graphic organizer into your notebook. Keep this page handy so that you can refer to it as you progress through Unit 4.

Science Skills

Go to Science Skill 11 to review how to use graphic organizers.

Chapter 10

The kinetic molecular theory explains the transfer of thermal energy.



When you feel the steely bite of winter rain or the warmth of sunlight, thermal energy is being transferred. The transfer of thermal energy is also behind the gentlest summer breeze and the most violent hurricane.

In this chapter, you will investigate how thermal energy is transferred. You will discover how the atmosphere captures and transports the thermal energy that sustains life on Earth—and sometimes threatens its existence. You will also learn how the atmosphere, like a blanket, protects Earth from deadly cold as well as radiation from space.

What You Will Learn

In this chapter, you will
- **define** heat, thermal energy, and atmospheric pressure
- **describe** Earth's sources of thermal energy
- **describe** how energy transfer affects the atmosphere
- **identify** weather conditions caused by high or low atmospheric pressure

Why It Is Important

Understanding the process of thermal energy transfer helps us to understand what causes the weather and how to better predict it.

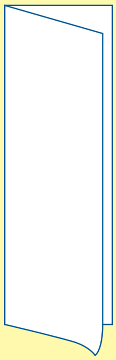
Skills You Will Use

In this chapter, you will
- **observe** the effects of atmospheric pressure
- **measure** temperature and atmospheric pressure
- **explain** and **model** the transfer of thermal energy
- **graph** atmospheric temperatures and experimental results

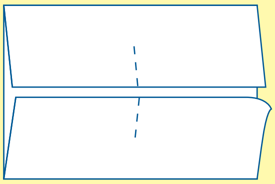
FOLDABLES™
Reading & Study Skills

Make the following Foldable to take notes on what you learn in Chapter 10.

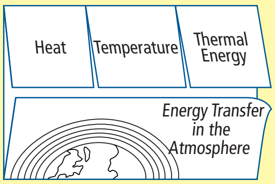
STEP 1 Use a sheet of 28 cm x 43 cm paper to create this modified shutterfold. **Fold** it as if you were going to make a hot dog, but instead of creasing the paper, **pinch** it to show the midpoint.



STEP 2 **Fold** the outer edges of the paper to meet at the pinch, or midpoint, forming a shutterfold.



STEP 3 **Hold** the shutterfold horizontally and **cut** the upper tab into thirds. Leave the bottom tab whole. **Label** the top three tabs as shown.



Record information, define key terms, and provide examples beneath the tabs. Glue or draw a half section image of Earth on the bottom tab showing the five levels of the atmosphere to create a quick visual reference. Beneath the tab, record information as you progress through the chapter.

10.1 Temperature, Thermal Energy, and Heat

The kinetic molecular theory explains that particles in matter are in constant motion. Matter has thermal energy due to the kinetic and potential energies of its particles. Heat is the amount of thermal energy transferred from a warmer area to a cooler one. Heat transfer occurs by collisions between particles (conduction), the movement of fluids (convection), or the movement of electromagnetic waves (radiation).

Words to Know

conduction
convection
electromagnetic radiation
heat
kinetic energy
kinetic molecular theory
temperature
thermal energy

Did You Know?

In outer space, far away from any planets, stars, or meteors, there are very few particles. However, even these few particles vibrate with kinetic energy. The Big Bang theory is one explanation for this phenomenon. Scientists suggest that the low level of energy in outer space is left over from the Big Bang, the expansion of the universe that began billions of years ago.

You have probably heard expressions like "this classroom is freezing," "this soup is too hot," or "it feels warm outside." All of these expressions may seem to refer to the same idea. However, each relates to a different concept: temperature, thermal energy, or heat. To understand the differences among these concepts, it is important to review the kinetic molecular theory.

As you may have learned in earlier science courses, the **kinetic molecular theory** explains that all matter is composed of particles (atoms and molecules). These particles move constantly in random directions. **Kinetic energy** is the energy of a particle or an object due to its motion. When particles collide, kinetic energy is transferred between them, much as a bowling ball transfers energy to the bowling pins it hits.

The particles of a substance are bonded together differently depending on the state of the substance. When the substance is in a solid state, the particles are very close together and vibrate slowly (Figure 10.1). When the same substance is in a liquid state, the particles are farther apart. When the same substance is in a gas state, the particles spread even farther apart. The particles of a substance move faster when the temperature of the substance increases.

Figure 10.1 Particles in a solid (right) are strongly attracted to one another. Particles in liquids (left) and gases (middle) move freely and are spread farther apart.

10-1A Heat It Up

Find Out ACTIVITY

According to the kinetic molecular theory, the more kinetic energy that particles have, the faster the particles will move and the more they will spread apart. In this activity, you will examine the relationship between particle motion and temperature.

Safety

- Use caution when handling the lamp as the light bulb will become very hot.

Materials

- alcohol thermometer
- 250 mL beaker
- cold water
- lamp with 100 W incandescent bulb

What to Do

1. Read the thermometer.
2. Fill the beaker with 100 mL of cold tap water. Use the thermometer to measure the temperature of the water.
3. Set up the lamp so that the light will shine directly on the beaker of water. Turn on the lamp.
4. Hold the thermometer in the beaker of water for at least 5 min. Observe the thermometer during this time.
5. Clean up and put away the equipment you have used.

What Did You Find Out?

1. State what you saw happening to the liquid in the thermometer:
   (a) when you took the first temperature reading
   (b) while the light was shining on the beaker of water
2. Explain your observations above using the kinetic molecular theory.
3. What made the temperature of the water change?
4. Why did it take time to get a temperature reading of the water?

Temperature

Even within a pure substance, in which the particles are identical, the kinetic energy of the particles will vary. The particles travel at different speeds and in different directions. **Temperature** is a measure of the average kinetic energy of all the particles in a sample of matter. A cup of hot chocolate feels hot because the average kinetic energy of its particles is higher than the average kinetic energy of the particles in your hand. As the particles' average kinetic energy increases, the temperature of a solid, liquid, or gas will also increase. For example, particles in a glass of cold water move slower and have less kinetic energy than particles in a cup of hot water (Figure 10.2).

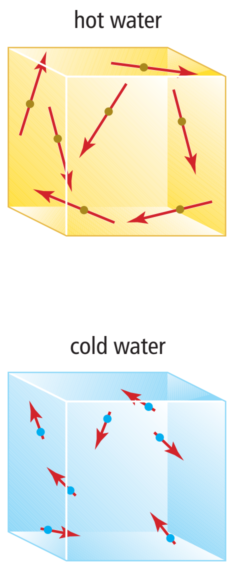


Figure 10.2 The dots represent water molecules. The arrows show how fast the water molecules are moving and in what direction.

Temperature scales

Three different number scales are used to measure temperature: Fahrenheit, Celsius, and Kelvin. The Fahrenheit scale was designed by the German-Dutch physicist Daniel Gabriel Fahrenheit (1686–1736) and has been used since 1724.

The Celsius scale was named after its inventor, the Swedish astronomer Anders Celsius (1701–1744). First used in 1745, the Celsius scale was later included in the metric system and is now used around the world. The Celsius scale is based on two fixed points: the freezing point of pure water (0°C) and the boiling point of pure water (100°C).

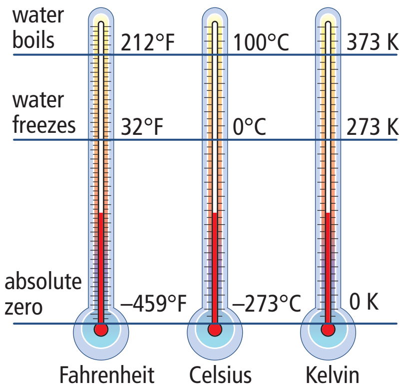


Figure 10.3 The temperature scales

In 1848, William Thompson (1824–1907) of Scotland proposed a temperature scale based on absolute zero, the temperature at which particles would have no kinetic energy. Thompson was later given the title Lord Kelvin, and so his scale is known as the Kelvin scale. Figure 10.3 gives the values of absolute zero and the freezing point and boiling point of water using the three different temperature scales.

Reading Check

1. What is the kinetic molecular theory?
2. Define temperature.
3. Name three temperature scales.

Thermal Energy

Thermal energy is the total energy of all the particles in a solid, liquid, or gas. The more kinetic energy a solid, liquid, or gas has, the more thermal energy it has. A hot bowl of soup, for example, has more thermal energy when it is first served than after it cools. Since thermal energy includes the energy of all of the particles in a sample of matter, a large bowl of soup would have more thermal energy than a small one. In fact, a swimming pool of lukewarm water would have more thermal energy than a small cup of hot tea.

Kinetic energy is not the only energy associated with moving particles (Figure 10.4). **Potential energy** is the stored energy of an object or particle, due to its position or state. An example is the gravitational attraction between Earth and a textbook you are holding. As you lift the textbook, its gravitational potential energy increases. The lower you hold the book, the less gravitational potential energy it has. Similarly, there are attractive electrical forces between atoms and molecules. The pull of these attractive forces gives particles potential energy.

Word Connect

The word "kinetic" comes from the ancient Greek word *kinetikos*, meaning to put in motion.

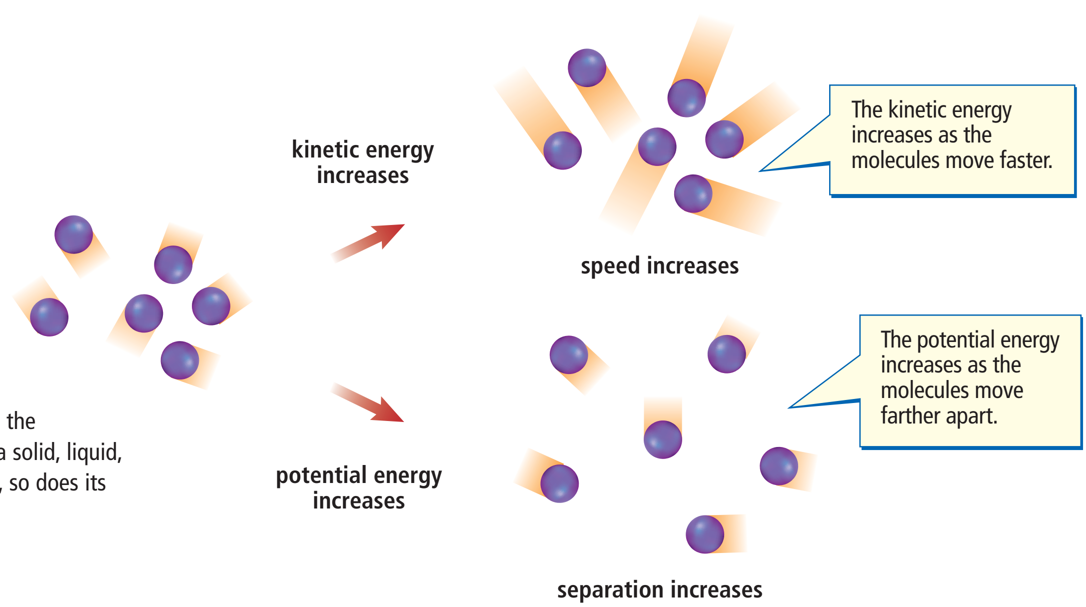


Figure 10.4 As the temperature of a solid, liquid, or gas increases, so does its thermal energy.

Heat

The terms "heat," "temperature," and "thermal energy" are often used as if they have the same meaning, but they do not. **Heat** is the amount of thermal energy that transfers from an area or object of higher temperature to an area or object of lower temperature. Consider how heat is used to cook an egg. Heat flows from the hot stove element to the frying pan and then to the egg. As the egg gains thermal energy, the kinetic energy of the egg's atoms and molecules increases, and so does its temperature. The egg heats up and cooks (Figure 10.5). Heat can similarly flow within and between large systems, such as the oceans and the atmosphere.

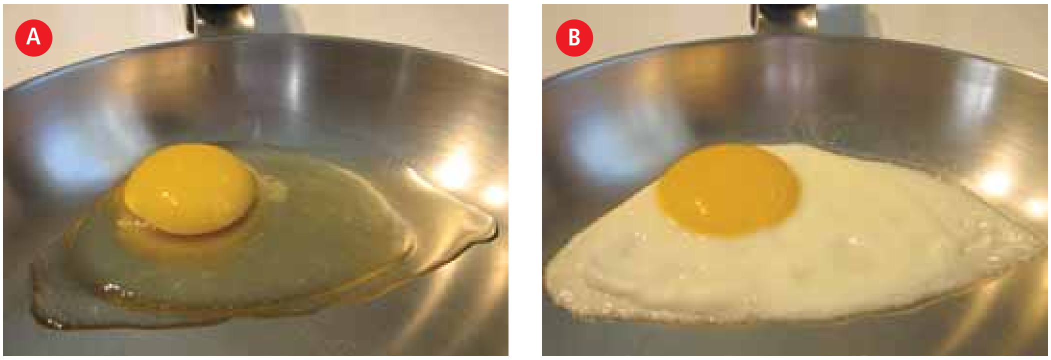


Figure 10.5 Heat transfers from the frying pan to the egg.

Reading Check

1. What term describes the total amount of energy of a solid, liquid, or gas?
2. How does temperature relate to thermal energy?
3. What is heat?

Heat Transfer

Heat can be transferred in three ways: conduction, convection, and radiation. Figure 10.6 shows a pot of boiling water on a stove. This figure illustrates all three types of heat transfer. The next three pages will describe the types of heat transfer in more detail.

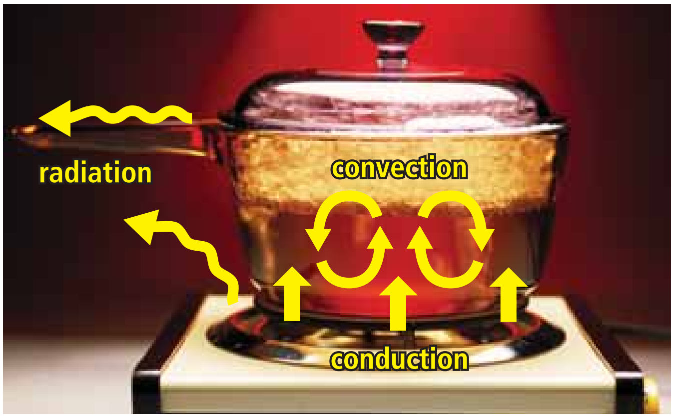


Figure 10.6 The stove element heats the pot and the pot heats the water by conduction. Water circulating in the pot transfers heat by convection. Near the stove, the air would feel warm due to heat transfer by radiation.

Conduction

Conduction is the transfer of heat from one substance to another or within a solid by direct contact of particles. Conduction transfers heat from matter with a higher temperature and greater kinetic energy to matter with a lower temperature and lower kinetic energy. This process explains why a metal spoon left in a pot of boiling water becomes hot to touch. The stove element heats the pot, which in turn heats the water. Heating increases the kinetic energy of the water molecules, which collide with particles in the spoon. The collisions transfer kinetic energy to the slower-moving particles of the spoon. As the collisions between particles continue, heat transfers to the spoon, making it feel hot.

Most materials can transfer heat by conduction, but they transfer it at different rates. Thermal conductors are materials that transfer heat easily. Metals, for example, are good thermal conductors. Materials that do not transfer heat easily are called insulators. Air, snow, wood, and Styrofoam® are examples of insulators (Figure 10.7).

Suggested Activity

Conduct an Investigation 10-1B on page 432

Did You Know?

On a cold winter day, if you touch anything metal, it feels very cold. However, the metal is not actually colder than the surrounding air. Most metals are excellent conductors and rapidly conduct thermal energy away from your hand. Your brain interprets the transfer of thermal energy to the metal as the sensation of cold.

Figure 10.7 Aluminum is a good thermal conductor (A). Styrofoam® is a good thermal insulator (B).

Reading Check

1. What term describes the transfer of heat by direct contact between particles?
2. What is the direction of heat transfer: higher temperature areas to lower temperature areas, or lower temperature area to higher temperature areas?
3. What is a conductor?
4. What is the term for a substance with low conductivity?

Convection

Liquids and gases are fluids. **Fluids** are substances in which the particles can flow freely. This characteristic allows for a second type of heat transfer, called convection. **Convection** is the transfer of heat within a fluid and with the movement of fluid from one place to another. Unlike conduction, convection transfers matter as well as heat.

The movement of liquid in a lava lamp occurs by convection. Melted rock under Earth's surface and clouds in the sky also move by convection (Figure 10.8).

internet connect

The horizontal transfer of heat in a fluid is called advection. To find out how ocean currents transfer heat by advection go to **www.bcscience10.ca**.

Figure 10.8 Convection currents are responsible for heat transfer in the lava lamp (A) and the lake of melted rock (B). Convection currents also produced the storm cloud (C).

Convection can be explained by the kinetic molecular theory. As particles move faster and their kinetic energy increases, they move farther apart. As the particles in a fluid move farther apart, the fluid itself expands and its density decreases. As you may have learned in earlier science courses, density is mass divided by volume. Therefore, if the mass of a sample of material remains the same but the volume increases, the density decreases.

Heating the air in a hot air balloon causes the air to expand. Because the air expands, it becomes lighter and the balloon can rise off the ground. Similarly, in a bubbling pot of water on the stove, the warmer water at the bottom of the pot rises because it is less dense than the surrounding water. At the surface, the water cools, contracts, and sinks—only to be reheated and recirculated. The movement of the water, caused by continuous cycling of heating, cooling, and reheating, is called a convection current. A **convection current** is the movement of a fluid caused by density differences.

Convection is used in a variety of household tools. Convection ovens use convection currents to transfer heat to food. Some home-heating systems also use convection (Figure 10.9). For example, a hot air furnace supplies warm air to a room through hot air vents. The warm air rises and then cools as it loses heat to surrounding air. The cooled air contracts and sinks, only to be reheated or replaced by incoming warm air. The convection current can therefore be used to warm an entire room.

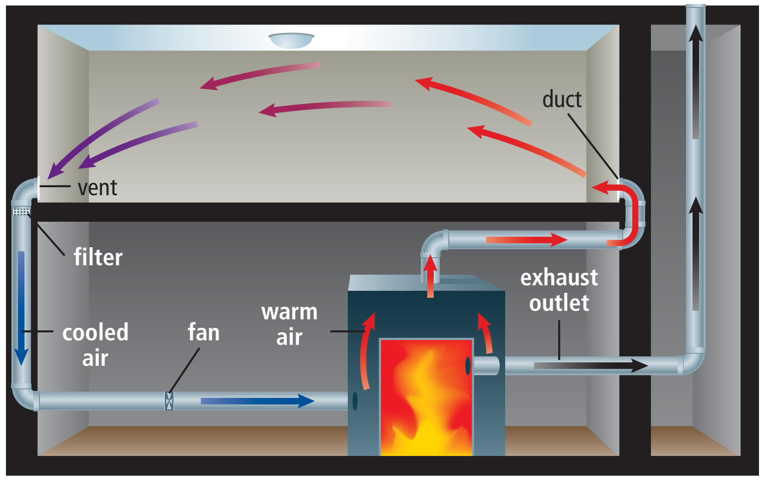


Figure 10.9 Hot air furnaces rely on convection currents to transfer heat throughout a room.

Suggested Activity

Conduct an Investigation 10-1C on page 433

Reading Check

1. What is the term for matter that can flow freely?
2. Does convection transfer heat or both heat and matter?
3. What happens to the density of an uncontained fluid when it is heated?
4. What is a convection current?

Radiation

Figure 10.10 Your body is a source of infrared radiation.

Without heat transfer from the Sun, life on Earth would not exist as we know it. But how can heat be transferred through space, where particles are spread so far apart that there is little chance they will collide? **Electromagnetic radiation**, is the transfer of energy by waves travelling outward in all directions from a source. Electromagnetic waves radiate (travel by radiation) through space even though there is no matter there. **Radiant energy** is the energy carried by electromagnetic waves.

The only electromagnetic radiation we can see is visible light. Most of the electromagnetic spectrum is invisible to the unaided human eye. However, if you stand too close to a campfire, you will experience the reality of **infrared radiation**, also known as heat radiation (Figure 10.10). When you stand in sunlight, your skin feels warm due to solar radiation, the transfer of radiant energy from the Sun (Figure 10.11 on the next page). **Solar radiation** is made up of visible light as well as infrared and other types of radiation (Figure 10.12 on the next page).

Any material with a temperature greater than absolute zero radiates some heat, including bicycle tires, baby diapers, ice cubes, oceans, and even you. Some materials transfer more heat than others. As you will read in Chapter 12, volcanic eruptions are a result of the release of thermal energy under Earth's surface. Scientists think that a great deal of thermal energy was stored as Earth formed from the build-up of dust into a bigger and bigger rocky lump. Some of this thermal energy was released over time. Residual thermal energy from Earth's formation continues to heat the planet. The decay of radioactive elements underground is another source of thermal energy on Earth.

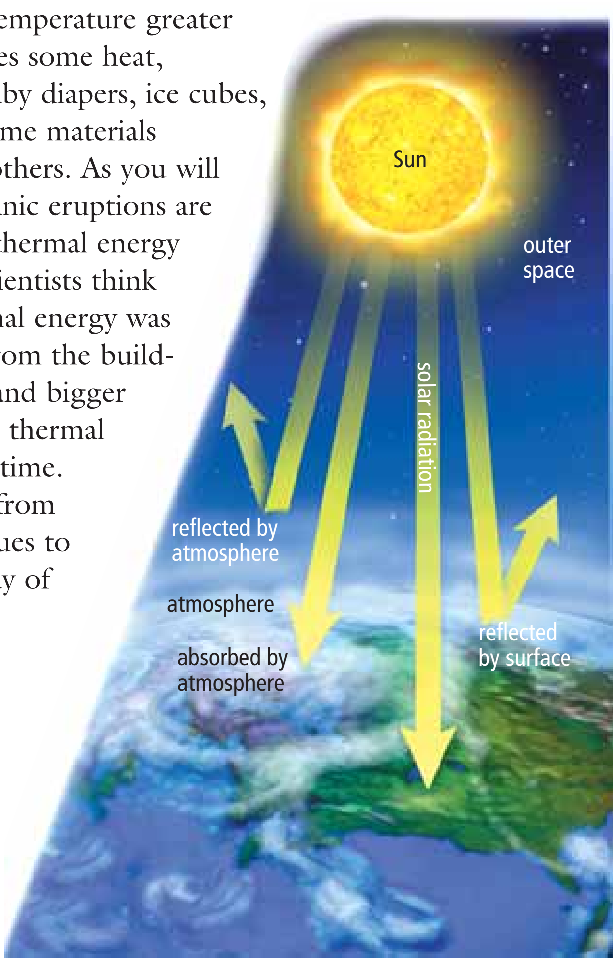


Figure 10.11 Solar radiation accounts for much of the thermal energy at Earth's surface.

Connection

Chapter 7 has more information on radiation.

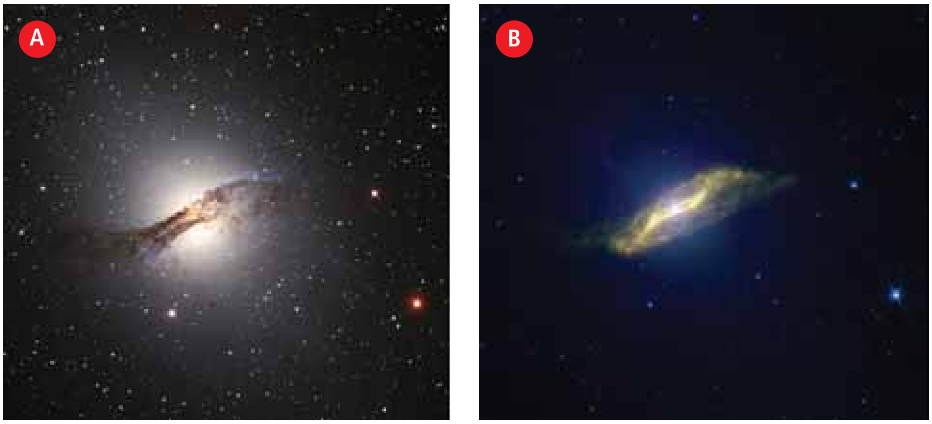


Figure 10.12 Like the Sun, this newly forming star is a source of both visible light (A) and infrared radiation (B).

Explore More

Find out more about scientists' hypotheses to explain how thermal energy became trapped in the newly formed Earth. Start your search at **www.bcscience10.ca**.

Materials absorb, reflect, or transmit radiation. Heat is transferred when a substance absorbs radiation, causing it to increase in temperature, melt, or evaporate. Section 10.2 explores what happens to solar radiation and how the transfer of thermal energy affects the atmosphere.

10-1B Conduction in Action

Conduct an INVESTIGATION

Inquiry Focus

Skill Check

- Observing
- Measuring
- Graphing
- Evaluating information

Safety

- Be careful not to burn yourself on the hot plate.
- Follow your teacher's safety instructions.

Materials

- four 8 cm conduction bars (steel, brass, copper, aluminum)
- felt pen
- ruler
- wax strips or candles
- matches
- hot plate
- brick or block of wood
- stopwatch
- graph paper
- coloured pens or pencil crayons

In this investigation, you will work with a group to test the ability of different types of metal to conduct heat.

Question

How can you investigate the rate of conductivity through different metals?

Procedure

1. Copy the following data table into your notebook. Give your table a title.

	Time (s)			
Distance (cm)	**Aluminum**	**Brass**	**Copper**	**Steel**
0.0	0.0	0.0	0.0	0.0
2.0				
8.0				

2. Label each metal bar with the felt pen: A (aluminum), B (brass), C (copper), and S (steel).
3. Use the ruler and felt pen to make marks along each bar at 1 cm intervals.
4. If you are using wax strips: Starting at the 2 cm mark, place a wax strip at every mark along each metal bar. If you are using candles: Light a candle. Starting at the 2 cm mark, carefully drop a spot of wax at every mark along each metal bar.
5. Place each of the metal bars on the hot plate, as shown in the above figure. Support the bars with your hand so that only the first 2 cm of each bar is on the hot plate.
6. To keep the metal bars from falling when you take away your hand, place a brick or block of wood on the ends of the bars that are touching the hot plate.
7. Turn on the hot plate, and start the stopwatch.
8. Observe how long it takes for the wax to melt at each position along each metal bar. Record the times in your data table. So that you do not miss any of the readings, each group member should be responsible for observing a particular metal bar.
9. Once the materials have cooled and are safe to touch, clean up and put away the equipment you have used.
10. Graph your results in a time versus distance graph. Using a different colour or symbol for each metal, draw four best-fit lines.

Analyze

1. How could you tell that heat was being conducted along the metal bars?
2. (a) Did all of the metals conduct heat equally well?
   (b) If not, rate the metals in order from best to worst thermal conductor.

Conclude and Apply

1. Use the kinetic molecular theory to explain how thermal energy was transferred along the metal bars.
2. Which of the metals would you use to stir a hot mixture? Explain your answer.

10-1C Coloured Convection Currents

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Observing
- Measuring
- Communicating
- Modelling

Safety

- Use caution when handling the hot water.
- Be careful using glass containers and thermometers.
- Follow your teacher's safety instructions.

Materials

- glass baking dish (approximately 4 cm × 12 cm × 30 cm)
- water (hot and cold)
- 2 ring stands
- 3 thermometer clamps
- 3 thermometers
- 250 mL beaker
- beaker tongs
- medicine dropper
- food colouring
- stopwatch
- 4 Styrofoam® or plastic cups to raise the baking dish

Particle movement affects the density of matter. In this investigation, you will model the flow of convection currents with liquid of varying temperatures and densities.

Question

How is thermal energy transferred in a fluid?

Procedure

1. Copy the following data table into your notebook. Allow enough rows to record the temperature every 10 s. Give your table a title.

	Temperature (°C)		
Times (s)	Thermometer 1	Thermometer 2	Thermometer 3
0			
10			
180			

2. Set up the apparatus as shown in the diagram. Fill the baking dish about $\frac{3}{4}$ full of cold tap water. Use the ring stands and thermometer clamps to submerse the thermometers in the water at three different positions.
3. Fill the beaker with about 225 mL of hot tap water. Use the medicine dropper to add several drops of food colouring to the water in the baking dish. Start the stopwatch. Record the temperature measured by each thermometer at time 0 s. Describe what you see.
4. Use the beaker tongs to carefully place the beaker of hot water under the centre of the baking dish. Continue to record the temperatures every 10 s for at least 3 min (or until the coloured water makes one complete circuit). Note the position of the coloured water every 30 s.
5. Clean up and put away the equipment you have used.

Analyze

1. Describe the motion of the coloured water from step 3 on.
2. Draw a cross-sectional sketch showing the path of the coloured water.
3. How did you measure the kinetic energy of the water at different locations?
4. How did the thermometer readings change with respect to the movement of the coloured water?

Conclude and Apply

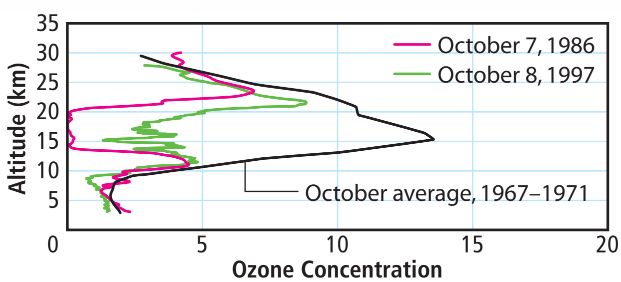
1. Compare the densities of cold and hot water.
2. Use the kinetic molecular theory to explain the movement of the coloured water.
3. (a) Like liquids, gases are fluids. Compare the densities of cold and hot air.
   (b) How might variations in the density of air lead to convection currents in the atmosphere?
4. What visible evidence could you look for that would indicate that there were convection currents in air?

Science Math connect

Graphing Earth's Ozone Profile

Our atmosphere contains a naturally occurring form of oxygen called ozone (O_3). The ozone layer does for the planet what sunscreen does for us when we expose our skin to sunlight. It blocks much of the harmful ultraviolet radiation from the Sun.

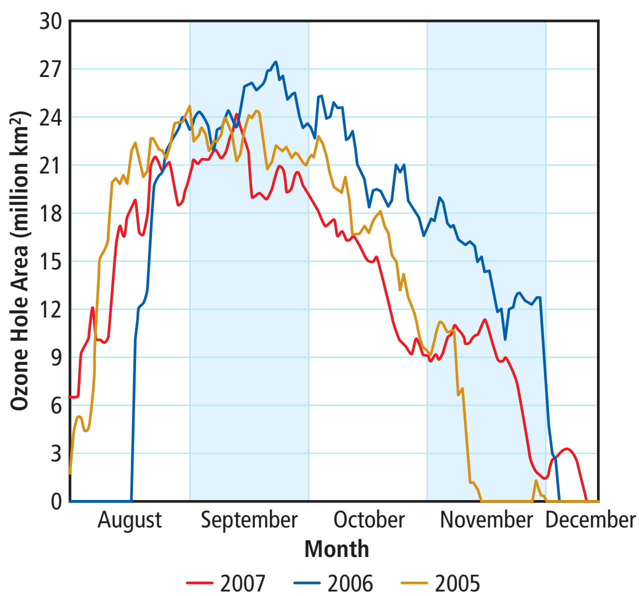
In the 1960s, scientists were surprised to observe a hole in the ozone layer over Antarctica. To get accurate data on the ozone layer, weather balloons were regularly launched from the ground in Antarctica. As they rose many kilometres into the air, instruments on the weather balloons measured ozone concentrations. Graph A compares ozone concentrations at different altitudes in October 1986 and 11 y later. The figure also shows the average ozone concentration at different altitudes for October between 1967 and 1971.



Graph A Ozone concentration at different altitudes

Graph A provides three kinds of information. First, altitude is plotted on the vertical (y) axis. The bottom of the graph shows ozone concentrations near the ground. As you follow each line up the graph, it shows the concentrations at higher altitudes. Second, the horizontal (x) axis shows ozone concentration. Notice how at 15 km the black line goes farthest of all to the right. This shows that, before the ozone hole opened up, the concentration of ozone at this altitude was relatively high. In comparison, the green and red lines show a drop to nearly zero concentration of ozone at 15 km. This comparison between measurements from different years is the third piece of information that the graph provides.

Scientists realized that certain chemicals used in cooling appliances and aerosol spray cans were destroying the ozone layer. Government regulations were eventually put in place to stop the use of ozone-depleting chemicals. Graph B shows the area of the ozone hole at different times between 2005 and 2007. To read the graph, follow the blue line until it reaches its highest point, which is in late September. At this point, the ozone hole was at its largest for the period between 2005 and 2007. The red line shows that in 2007 the ozone hole was smaller than in 2006 (blue) and 2005 (orange). The downward trend is good news. It suggests that efforts to stop ozone depletion are working.



Graph B Area of ozone hole over Antarctica

Questions

1. At what altitude was ozone at its highest concentration on October 7, 1986?
2. (a) Which range of altitudes was most severely affected by ozone depletion?
   (b) Why is ozone depletion in this range a problem?
3. Estimate when in 2007 the size of the ozone hole reached 24 million km^2.

Check Your Understanding

Checking Concepts

1. Copy and complete the following question in your notebook. Match the term in column A with the correct description in column B.

A		B
(i) heat	____	(a) the total energy of all the particles in a solid, liquid, or gas
(ii) temperature	____	(b) amount of thermal energy transferred between different areas or objects
(iii) thermal energy	____	(c) the energy of a particle or object due to its motion
(iv) kinetic energy	____	(d) a measure of the average kinetic energy of all the particles in a sample of matter

2. Name the correct temperature scale (Fahrenheit, Celsius, or Kelvin) for each of the following values. The values are the temperatures at absolute zero (the temperature at which all particle motion stops).
   (a) 0°
   (b) −273°
   (c) −460°
3. Create a table to compare and contrast the transfer of heat by conduction and convection. Use the following headings in your table.
   - States of Matter Involved
   - Examples of Materials Involved
   - How Particles Interact
   - What Is Transferred?
4. If you leave lights on in a closed room, the air inside the room will start to feel hot. What type of energy transfer is involved in this situation? Explain.
5. What part of the electromagnetic spectrum makes the sidewalk feel warm on a sunny day?

Understanding Key Ideas

6. Explain how thermal energy is transferred from a hot stove element to soup in a pot. Refer to the motion of atoms and molecules in your response.
7. Can conduction occur between a hot beaker and your hand if you do not touch the beaker? Explain.
8. Suppose you pour some hot water into a sink full of cold dishwater. What could you do to make the water in the sink heat up more evenly? Use the kinetic molecular theory to explain your answer.
9. Why does a house with a snow-covered roof stay warmer inside than it would if there were no snow on the roof?
10. Name the type of heat transfer indicated by each letter in the following photograph.

Pause and Reflect

On a hot day, you might have heard someone say that it is "hot enough to fry an egg on the sidewalk!" Explain how radiation and conduction would make this possible.