21 Chapter Assessment

Temperature, Heat & Expansion

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Concept Summary

Temperature is the measurement that tells how warm or cold something is.

- Temperature is directly proportional to the average translational kinetic energy of the molecules within an ideal gas.

Heat is energy that transfers between two things due to a temperature difference.

- Matter does not contain heat; rather, it contains internal energy.

Specific heat is a measure of how much heat is required to raise the temperature of a unit mass of a substance by one degree.

- Water has a much higher specific heat than other common substances.

Matter tends to expand when heated and to contract when cooled.

- Liquids usually expand slightly more than solids.
- Gases expand much more than liquids or solids for comparable increases in temperature (and comparable pressure).
- Water is highly unusual in that it contracts as it warms from 0°C to 4°C and its solid form (ice) is less dense than its liquid form.

Key Terms

absolute zero (21.1)
bimetallic strip (21.8)
calorie (21.5)
Celsius scale (21.1)
Fahrenheit scale (21.1)
heat (21.2)
internal energy (21.4)
Kelvin scale (21.1)
kilocalorie (21.5)
specific heat capacity (21.6)
temperature (21.1)
thermal contact (21.2)
thermal equilibrium (21.3)
thermostat (21.8)

Review Questions *Check Concepts*

1. How is temperature commonly measured? (21.1)
2. How many degrees are between the melting point of ice and boiling point of water on the Celsius scale? Fahrenheit scale? (21.1)
3. Why is it incorrect to say that matter *contains* heat? (21.2)
4. In terms of differences in temperature between objects in thermal contact, in what direction does heat flow? (21.2)
5. What is meant by saying that a thermometer measures its own temperature? (21.3)
6. What is thermal equilibrium? (21.3)
7. What is internal energy? (21.4)
8. What is the difference between a calorie and a Calorie? (21.5)
9. What does it mean to say that a material has a high or low specific heat capacity? (21.6)

10. Do substances that heat up quickly normally have high or low specific heat capacities? (21.6)

11. How does the specific heat capacity of water compare with that of other common substances? (21.7)

12. Why is the North American west coast warmer in winter months and cooler in summer months than the east coast? (21.7)

13. Why does a bimetallic strip curve when it is heated (or cooled)? (21.8)

14. Which expands most for increases in temperature: solids, liquids, or gases? (21.8)

15. At what temperature is the density of water greatest? (21.9)

16. Ice is less dense than water because of its open crystalline structure. But why is water at 0°C less dense than water at 4°C? (21.9)

17. Why do lakes and ponds freeze from the top down rather than from the bottom up? (21.9)

18. Why do shallow lakes freeze quickly in winter, and deep lakes not at all? (21.9)

Plug and Chug *Use Equations*

Heat transfer in calories is given by $Q = mc\Delta T$, where m is mass in grams, c is specific heat capacity in cal/g°C, and ΔT is in °C.

19. Calculate the number of calories of heat needed to change 500 grams of water by 50 Celsius degrees.

20. Calculate the number of calories given off by 500 grams of water cooling from 50°C to 20°C.

21. A 30-gram piece of iron is heated to 100°C and then dropped into cool water where the iron's temperature drops to 30°C. How many calories does it lose to the water? (The specific heat capacity of iron is 0.11 cal/g°C.)

22. Suppose the same 30-gram piece of iron is dropped into another container of water and gives off 165 calories in cooling. Calculate the iron's temperature change.

23. What mass of water will give up 240 calories when its temperature drops from 80°C to 68°C?

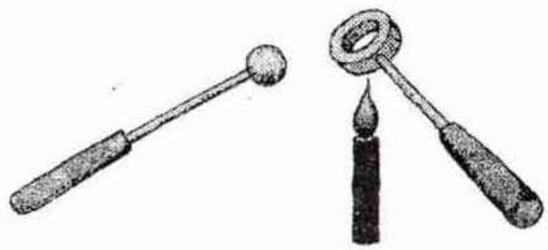
24. When a 50-gram piece of aluminum at 100°C is placed in water, it loses 735 calories of heat while cooling to 30°C. Calculate the specific heat capacity of the aluminum.

Think and Explain *Think Critically*

25. If you drop a hot rock into a pail of water, the temperature of the rock and the water will change until both are equal. The rock will cool and the water will warm. Does the same principle hold true if the rock is dropped into a large lake? Explain.

26. If you stake out a plot of land with a steel tape measure using map measurements on a very hot day, will you enclose more or less land than on a very cold day?

27. A metal ball is just able to pass through a metal ring. When the ball is heated, thermal expansion will not allow it to pass through the ring. What would happen if the ring, rather than the ball, were heated? Would the ball pass through the heated ring? Does the size of the hole in the ring increase, decrease, or stay the same?



28. A snugly fitting steel pipe circling the world would stand about 64 meters off the ground if its temperature were increased by 1°C. What would be the result if the pipe were instead cooled by 1°C?

29. After a machinist slips a hot, snugly fitting iron ring over a cold brass cylinder, the ring becomes "locked" in position and can't be removed even by subsequent heating. This procedure is called "shrink fitting." How does it occur? Can you conclude anything about the thermal expansion rates of iron and brass?

30. If you take a bite of hot pizza, the sauce may burn your mouth while the crust, at the same temperature, will not. Explain.

31. In the old days, on a cold winter night it was common to bring a hot object to bed with you. Which would be better—a 10-kilogram iron brick or a 10-kilogram jug of hot water at the same temperature? Explain.

32. On a hot day you remove from a picnic cooler a chilled watermelon and some chilled sandwiches. Which will remain cool for a longer time? Why?

33. Iceland, so named to discourage conquest by expanding empires, is not at all ice-covered like Greenland and parts of Siberia, even though it is nearly on the Arctic Circle. The average winter temperature of Iceland is considerably higher than regions at the same latitude in eastern Greenland and central Siberia. Why is this so?

34. Why is it important to protect water pipes so they don't freeze?

35. Suppose you cut a small gap in a metal ring, as shown. If you heat the ring, will the gap become wider or narrower?

36. Would a bimetallic strip function if the two different metals happened to have the same rates of expansion? Is it important that they expand at different rates? Explain.

37. State whether water at the following temperatures will expand or contract when warmed: 0°C; 4°C; 6°C.

38. In addition to the overall motion of molecules that is associated with temperature, some molecules can absorb large amounts of energy in the form of internal vibrations and rotations of the molecules themselves. Would you expect materials composed of such molecules to have a high or a low specific heat capacity? Why?

39. If water had a lower specific heat capacity, would lakes be more likely or less likely to freeze in the winter?

Think and Solve

Develop Problem-Solving Skills

40. If you wished to warm 100 kg of water by 15°C for your bath, how much heat would be required? (Give your answer in calories and joules.)

41. What would be the final temperature if you mixed a liter of 20°C water with 2 liters of 40°C water?

42. What would be the final temperature if you mixed a liter of 40°C water with 2 liters of 20°C water?

43. What would be the final temperature of the mixture of 50 g of 20°C water and 50 g of 40°C water?

44. What would be the final temperature when 100 g of 25°C water is mixed with 75 g of 40°C water?

45. What is the specific heat capacity of a 50-gram piece of 100°C metal that will change 400 grams of 20°C water to 22°C?

46. Suppose that a metal bar 1 m long expands 0.5 cm when it is heated. How much would it expand if it were 100 m long?

47. Steel expands 1 part in 100 000 for each 1°C increase in temperature. If the 1.5-km main span of a steel suspension bridge had no expansion joints, how much longer would it be for a temperature increase of 20°C?

48. What will be the final temperature of 100 g of 20°C water when 100 g of 40° iron nails are submerged in it? (The specific heat of iron is 0.12 cal/gC°.)

More Problem-Solving Practice
Appendix F

22 Chapter Assessment

Heat Transfer

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Concept Summary

Heat transfer by conduction takes place within certain materials and from one material to another when in contact.

- Metals are good conductors.
- Poor conductors, such as wood, cork, polystyrene, and most liquids and gases, are good insulators.

Heat transfer by convection takes place by the movement of heated material itself.

- Convection occurs in all fluids (both liquids and gases).
- Winds result from convection currents that stir the atmosphere.

Heat transfer by radiation takes place from everything to everything, even in empty space.

- Energy transmitted by radiation is called radiant energy.
- A good absorber of radiant energy reflects very little radiant energy, including visible light, and thus appears dark.
- Good absorbers of radiant energy are good emitters.
- According to Newton's law of cooling, the rate of cooling (or warming) of an object is approximately proportional to the temperature difference between the object and its surroundings.

Key Terms

conduction (22.1)
conductor (22.1)
convection (22.2)
greenhouse effect (22.7)
insulator (22.1)
Newton's law of cooling (22.6)
radiant energy (22.3)
radiation (22.3)
terrestrial radiation (22.7)

Review Questions *Check Concepts*

1. What is the rôle of "loose" electrons in heat conductors? (22.1)
2. Why does a piece of room-temperature metal feel cooler to the touch than paper, wood, or cloth? (22.1)
3. What is the difference between a conductor and an insulator? (22.1)
4. Why are materials such as wood, fur, feathers, and even snow good insulators? (22.1)
5. What is meant by saying that cold is not a tangible thing? (22.1)
6. How does Archimedes' principle relate to convection? (22.2)
7. Why does the direction of coastal winds change from day to night? (22.2)
8. How does the temperature of a gas change when it is compressed? When it expands? (22.2)
9. Dominoes are placed upright in a row, one next to another. When one is tipped over, it knocks against its neighbor, which does the same in cascade fashion until the whole row collapses. Which of the three types of heat transfer is this most similar to? (22.1–22.3)

10. What is radiant energy? (22.3)

11. How do the wavelengths of radiant energy vary with the temperature of the radiating source? (22.3)

12. Why does a good absorber of radiant energy appear black? (22.4)

13. Why do eye pupils appear black? (22.4)

14. Is a good absorber of radiation a good emitter or a poor emitter? (22.5)

15. Which will normally cool faster, a black pot of hot tea or a silvered pot of hot tea? (22.5)

16. Which will undergo the greater rate of cooling, a red-hot poker in a warm oven or a red-hot poker in a cold room (or do both cool at the same rate)? (22.6)

17. Does Newton's law of cooling apply to warming as well as to cooling? (22.6)

18. What is terrestrial radiation? (22.7)

19. Solar radiant energy is composed of short waves, yet terrestrial radiation is composed of relatively longer waves. Why? (22.7)

20. **a.** What does it mean to say that the greenhouse effect is like a one-way valve?

b. Is the greenhouse effect more pronounced for florists' greenhouses or for Earth's surface? (22.7)

Think and Explain *Think Critically*

21. At what common temperature will both a block of wood and a piece of metal feel neither hot nor cool when you touch them with your hand?

22. If you stick a metal rod in a snowbank, the end in your hand will soon become cold. Does cold flow from the snow to your hand?

23. Wood is a poor conductor, which means that heat is slow to transfer—even when wood is very hot. Why can firewalkers safely walk barefoot on red-hot wooden coals, but not safely walk barefoot on red-hot pieces of iron?

24. Notice that a desk lamp often has small holes near the top of the metal lampshade. How do these holes keep the lamp cool?

25. When a space shuttle is in orbit and there appears to be no gravity in the cabin, why can a candle not stay lit?

26. In Montana, the state highway department spreads coal dust on top of snow. When the sun comes out, the snow rapidly melts. Why?

27. Suppose that a person at a restaurant is served coffee before he or she is ready to drink it. In order that the coffee be hottest when the person is ready for it, should cream be added to it right away or just before it is drunk?

28. Will a can of beverage cool just as fast in the regular part of the refrigerator as it will in the freezer compartment? (What physical law do you think about in answering this?)

29. If you wish to save fuel on a cold day, and you're going to leave your warm house for a half hour or so, should you turn your thermostat down a few degrees, down all the way, or leave it at room temperature?

30. If the composition of the upper atmosphere were changed so that it permitted a greater amount of terrestrial radiation to escape, what effect would this have on Earth's climate? Conversely, what would be the effect if the upper atmosphere reduced the escape of terrestrial radiation?

Activities *Performance Assessment*

31. If you live where there is snow, do as Benjamin Franklin did nearly two centuries ago and lay samples of light and dark cloth on the snow. (If you don't live in a snowy area, try this using ice cubes.) Describe differences in the rate of melting beneath the cloths.

32. Wrap a piece of paper around a thick metal bar and place it in a flame. Note that the paper will not catch fire. Can you figure out why? (*Hint:* Paper generally will not ignite until its temperature reaches about 230°C.)

More Problem-Solving Practice
Appendix F

Chapter Assessment

23 Change of Phase

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Concept Summary

During evaporation, a liquid changes phase at its surface and becomes a gas.

- Evaporation is a cooling process.

During condensation, a gas changes phase and becomes a liquid.

- Condensation is a warming process.
- At the same relative humidity, there is more water vapor in warm air than in cold air.
- Clouds and fog form when air cools and is unable to contain as much water vapor.

When evaporation and condensation occur at the same rate, the liquid is in equilibrium and there is no change in the liquid's volume.

- A liquid is in equilibrium when the surrounding air is saturated with its vapor.
- In dry air, water evaporates much faster than it condenses; in humid air, it evaporates only slightly faster than it condenses

During boiling, a liquid changes phase at any place within the liquid, and gas bubbles form.

- The boiling temperature of a liquid depends on the pressure on its surface.
- Boiling, like evaporation, is a cooling process.

During freezing, a liquid changes phase and becomes a solid.

- The freezing temperature of a liquid is lowered by adding other substances to it.
- During regelation, ice melts under pressure and refreezes when the pressure is removed.

During phase changes, energy is given off or taken in.

- While a substance changes phase, its temperature does not change.
- Much more energy is given off when water vapor condenses than when an equal mass of water freezes.

Key Terms

boiling (23.4)	phase (23.0)
condensation (23.2)	regelation (23.7)
equilibrium (23.3)	relative humidity (23.2)
evaporation (23.1)	saturated (23.2)
freezing (23.5)	

Review Questions *Check Concepts*

1. Do all the molecules or atoms in a liquid have about the same speed, or much different speeds? (23.1)
2. What is evaporation, and why is it also a cooling process? (23.1)
3. Why does a dog pant on a hot day? (23.1)
4. What is condensation, and why is it also a warming process? (23.2)
5. Why is being burned by steam more damaging than being burned by boiling water of the same temperature? (23.2)
6. Which usually contains more water vapor—warm air or cool air? (23.2)
7. Why does warm moist air form clouds when it rises? (23.2)
8. Why do you feel less chilly if you dry yourself inside the shower stall after taking a shower? (23.3)

9. How can you tell if the rate of evaporation equals the rate of condensation? (23.3)

10. What is the difference between evaporation and boiling? (23.4)

11. Why does the temperature at which a liquid boils depend on atmospheric pressure? (23.4)

12. Why is a pressure cooker even more useful when cooking food in the mountains than when cooking at sea level? (23.4)

13. Why does antifreeze or any soluble substance put in water lower its freezing temperature? (23.5)

14. How can water be made to both boil and freeze at the same time? (23.6)

15. What is regelation, and what does it have to do with the open-structured crystals in ice? (23.7)

16. a. How many calories are needed to raise the temperature of 1 gram of water by 1°C?

    b. How many calories are needed to melt 1 gram of ice at 0°C?

    c. How many calories are needed to vaporize 1 gram of boiling water at 100°C? (23.8)

17. Does a vapor give off or absorb energy when it turns into a liquid? (23.8)

18. What is the effect of rapid evaporation on the temperature of water? (23.8)

19. In a refrigerator, does the food cool when a vapor turns to a liquid, or vice versa? (23.8)

20. Why is it important that a finger be wet before it is touched briefly to a hot clothes iron? (23.8)

Plug and Chug *Use Equations*

Quantity of heat energy required for change of phase = (mass) × (heat of fusion or heat of vaporization), or in equation form,
$Q = mL$

Quantity of heat energy responsible for a temperature change = (mass) × (specific heat) × (change in temperature), or in equation form,
$Q = mc\Delta T$

For water, heat of fusion = 80 cal/g; heat of vaporization = 540 cal/g.

21. Calculate the energy (in calories) absorbed by 20 grams of water that warms from 30°C to 90°C.

22. Calculate the energy needed to melt 50 grams of 0°C ice.

23. Calculate the energy needed to melt 100 grams of 0°C ice and then heat it to 30°C.

24. Calculate the energy absorbed by 20 grams of 100°C water that is turned into 100°C steam.

25. Calculate the energy released by 20 grams of 100°C steam that condenses and then cools to 0°C.

Think and Explain *Think Critically*

26. a. Evaporation is a cooling process. What cools and what warms during evaporation?

    b. Condensation is a warming process. What warms and what cools during condensation?

27. You can determine wind direction if you wet your finger and hold it up into the air. Explain.

28. Give two reasons why pouring a hot cup of coffee into a saucer results in faster cooling.

29. At a picnic, why would wrapping a bottle in a wet cloth be a better method of cooling than placing the bottle in a bucket of cold water?

30. Why is the constant temperature of boiling water on a hot stove evidence that boiling is a cooling process? (What would happen to its temperature if boiling were not a cooling process?)

31. Will potatoes boiling in a pot of water cook faster if the water is boiling vigorously than if the water is boiling gently?

32. People who live where snowfall is common will attest to the fact that air temperatures are generally higher on snowy days than on clear days. Some people get cause and effect mixed up when they say that snowfall cannot occur on very cold days. Explain.

33. If a large tub of water is kept in a small unheated room, even on a very cold day the temperature of the room will not go below 0°C. Why not?

34. On cold winter days the windows of your warm home sometimes get wet on the inside. Why is this so?

35. On a clear night, why does more dew form in an open field than under a tree or beneath a park bench?

Think and Solve

Develop Problem-Solving Skills

36. How much steam at 100°C must be condensed in order to melt 1 gram of 0°C ice and have the resulting ice water remain at 0°C? (The answer is *not* 0.148 grams!)

37. Calculate the energy released by 1 gram of 100°C boiling water that cools to form ice, and then continues releasing energy until it reaches absolute zero. (Absolute zero is –273°C, and the specific heat capacity of ice over this broad temperature range averages about 0.3 cal/g°C.)

38. Calculate the energy released by 1 gram of 100°C steam condensing to 1 gram of boiling water of the same temperature. How does this energy compare with the energy released in the previous problem?

39. How many calories are given off by 1 gram of 100°C steam that changes phase to 1 gram of ice at 0°C.

40. Compare the heat given off by 1 gram of steam that condenses to boiling water, to the heat given off by 1 gram of boiling water that cools to form ice, and then continues giving off energy all the way to absolute zero. (The specific heat of ice is 0.5 cal/gram°C.)

41. If 20 grams of hot water at 80°C is poured into a cavity in a very large block of ice at 0°C, what will be the final temperature of the water in the cavity? How much ice must melt in order to cool the hot water down to this temperature?

42. If a 100-g piece of iron is heated to 100°C and then dropped into a cavity in a large block of ice at 0°C, how much ice will melt? (The specific heat capacity of iron is 0.11 cal/g°C.)

Answer questions 43–47 in terms of joules rather than calories.

43. How much energy is needed to melt 5 kg of ice at 0° C?

44. How much energy is given to your body when 0.5 kg of steam condenses on your skin?

45. If that same amount of energy (answer to question 44) were used to warm 4 kg of water (8 times as much!) initially at 0° C, what would be the final temperature of the water?

46. The heat of vaporization of ethyl alcohol is 8.5×10^5 J/kg. If 2 kg of it were allowed to vaporize in a refrigerator, how much energy would be drawn from the air molecules?

47. How much energy is needed to change 1 kg of ice at –10° C to steam at 120° C?

Activity *Performance Assessment*

48. Boil some water in a pan and note that bubbles form at particular regions of the pan. These are nucleation sites—scratched or flawed regions of the pan, or simply bits of crud. When water reaches the boiling point these sites provide havens where microscopic bubbles can collect long enough to become big bubbles. Nucleation sites are also important for phase changes of condensation and solidification. Snowflakes and raindrops typically form around dust particles, for example.

More Problem-Solving Practice
Appendix F

24 Chapter Assessment

Thermodynamics

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Concept Summary

Thermodynamics is the study of heat and work.

- Absolute zero is the lowest possible temperature that a substance may have; where molecules of a substance have minimum kinetic energy.

First law of thermodynamics: The heat added to a system equals the sum of the increase in internal energy plus the external work done by the system. This is a restatement of the law of energy conservation applied to heat.

- An adiabatic process is one usually of expansion or compression, wherein no heat enters or leaves a system.

Second law of thermodynamics: Heat does not spontaneously flow from a cold object to a hot object. No machine can be completely efficient in converting energy to work; some input energy is dissipated as heat. All systems tend to become more and more disordered as time goes by.

Entropy is a measure of the disorder of a system. Whenever energy freely transforms from one form to another, the direction of transformation is toward a state of greater disorder (greater entropy).

Key Terms

absolute zero (24.1)
adiabatic (24.3)
Carnot efficiency (24.5)
entropy (24.7)
first law of thermodynamics (24.2)
heat engine (24.5)
second law of thermodynamics (24.4)
thermodynamics (24.0)

Review Questions *Check Concepts*

1. What is the meaning of the Greek words from which we get the word *thermodynamics*? (24.0)
2. Is the study of thermodynamics concerned primarily with microscopic or macroscopic processes? (24.0)
3. What is the lowest possible temperature on the Celsius scale? On the Kelvin scale? (24.1)
4. What is the temperature of melting ice in kelvins? Of boiling water? (24.1)
5. How does the law of the conservation of energy relate to the first law of thermodynamics? (24.2)
6. What happens to the internal energy of a system when work is done on it? What happens to its temperature? (24.2)
7. What is the relationship between heat added to a system and the internal energy and external work done by the system? (24.2)
8. If work is done adiabatically on a system, will the internal energy of the system increase or decrease? If work is done by a system, will the internal energy of the system increase or decrease? (24.2)
9. What condition is necessary for a process to be adiabatic? (24.3)
10. What happens to the temperature of air when it is adiabatically compressed? When it adiabatically expands? (24.3)
11. What generally happens to the temperature of rising air? (24.3)
12. What generally happens to the temperature of sinking air? (24.3)
13. How does the second law of thermodynamics relate to the direction of heat flow? (24.4)
14. What three processes occur in every heat engine? (24.5)
15. What is thermal pollution? (24.5)

16. If all friction could be removed from a heat engine, would it be 100% efficient? Explain. (24.5)

17. What is the ideal efficiency of a heat engine that operates with its hot reservoir at 500 K and its sink at 300 K? (24.5)

18. Why are heat engines intentionally run at high operating temperatures? (24.5)

19. Give at least two examples to distinguish between organized energy and disorganized energy. (24.6)

20. How much of the electrical energy transformed by a common lightbulb becomes heat energy? (24.6)

21. With respect to orderly and disorderly states, what do natural systems tend to do? Can a disorderly state ever transform to an orderly state? Explain. (24.6)

22. What is the physicist's term for a measure of messiness? (24.7)

23. Under what condition can entropy decrease in a system? (24.7)

24. What is the relationship between the second law of thermodynamics and entropy? (24.7)

25. Distinguish between the first and second laws of thermodynamics in terms of whether or not exceptions occur. (24.7)

Plug and Chug *Use Equations*

26. Calculate the ideal efficiency of a heat engine that takes in energy at 800 K and expels heat to a reservoir at 300 K.

27. Calculate the ideal efficiency of a ship's boiler when steam comes out at 530 K, pushes through a steam turbine, and exits into a condenser that is kept at 290 K by circulating seawater.

28. Calculate the ideal efficiency of a steam turbine that has a hot reservoir of 112°C high-pressure steam and a sink at 27°C.

29. In a heat engine driven by ocean temperature differences, the heat source (water near the surface) is at 293 K and the heat sink (deeper water) is at 283 K. Calculate the ideal efficiency of the engine.

Think and Explain *Think Critically*

30. A friend said the temperature inside a certain oven is 600 and the temperature inside a certain star is 60 000. You're unsure about whether your friend meant kelvins or degrees Celsius. How much difference does it make in each case?

31. When you pump a tire with a bicycle pump, the cylinder of the pump becomes hot. Give two reasons why this is so.

32. Is it possible to entirely convert a given amount of heat into mechanical energy? Is it possible to entirely convert a given amount of mechanical energy into heat? Cite examples to illustrate your answers.

33. We know that warm air rises. So it might seem that the air temperature should be higher at the top of mountains than down below. But the opposite is most often the case. Why?

34. Will the efficiency of a car engine increase, decrease, or remain the same if the muffler is removed? If the car is driven on a very cold day? Defend your answers.

35. The combined molecular kinetic energies of molecules in a very large container of cold water are greater than the combined molecular kinetic energies in a cup of hot tea. Pretend you partially immerse the teacup in the cold water and that the tea absorbs 10 joules of energy from the water and becomes hotter, while the water that gives up 10 joules of energy becomes cooler. Would this energy transfer violate the first law of thermodynamics? The second law of thermodynamics? Explain.

36. A mixture of fuel and air is burned rapidly in a combustion engine to push a piston in the engine that in turn propels the vehicle. In a jet engine a mixture of fuel and air is burned rapidly and, instead of pushing pistons, pushes the aircraft itself. Which do you suppose is more efficient?

37. Suppose one wishes to cool a kitchen by leaving the refrigerator door open and closing the kitchen door and windows. What will happen to the room temperature? Why?

38. In buildings that are being heated electrically, is it wasteful to turn on all the lights? Is turning on all the lights wasteful if the building is being cooled by air conditioning? Defend your answers.

39. Water put into a freezer compartment in your refrigerator goes to a state of less molecular disorder when it freezes. Is this an exception to the entropy principle? Explain.

40. On a cold 10°C day, your friend who likes cold weather says she wishes it were twice as cold. Taking this to mean she wishes the air had half the internal energy, what temperature would this be?

41. Why is "thermal pollution" a relative term?

42. Is it possible to construct a heat engine that produces no thermal pollution? Defend your answer.

43. What happens to the efficiency of a heat engine when the temperature of the reservoir into which heat energy is rejected is lowered?

Think and Solve

Develop Problem-Solving Skills

44. Helium has the special property that its internal energy is directly proportional to its absolute temperature. Consider a flask of helium with a temperature of 10°C. If it is heated until it has twice the internal energy, what will its temperature be?

45. A heat engine takes in 100 kJ of energy from a source at 800 K and expels 50 kJ to a reservoir at 300 K. Calculate the ideal efficiency and the actual efficiency of the engine.

46. Which heat engine has greater ideal efficiency, one that operates between the temperatures 600 K and 400 K or one that operates between 500 K and 400 K? Explain how your answer conforms to the idea that a higher operating temperature yields higher efficiency.

47. To increase the efficiency of a heat engine, would it be better to increase the temperature of the reservoir while holding the temperature of the sink constant, or to decrease the temperature of the sink while holding the temperature of the reservoir constant? Show your work.

48. What is the ideal efficiency of an automobile engine wherein fuel is heated to 2700 K and the outdoor air is 300 K?

49. Imagine a giant dry-cleaner's bag full of air at a temperature of –35°C floating like a balloon with a string hanging from it 10 km above the ground. Estimate its temperature if you were able to yank it suddenly to Earth's surface.

More Problem-Solving Practice
Appendix F