Chapter 15

First Law of Thermodynamics

15.1 Internal energy and work in gas processes

OALG 15.1.1 Derive

You have a container filled with a gas at known conditions (its molar mass, the number of moles, and the temperature).

a. In Chapter 12, you learned how the average kinetic energy of a particle of ideal gas is related to the temperature of the gas. Use this knowledge to derive an expression for the internal energy of the gas, assuming the gas is ideal. If you are having difficulties, read and interrogate sub-section "Thermal energy of ideal gas" in Section 15.1 in the textbook.

b. How will the internal energy of the same amount of gas change if you place it in a container with a larger volume while keeping the gas temperature the same? Explain.

c. Imagine that you separate the gas into two equal containers, which are half the size of the original container. Compare the internal energy of the gas in each container with the energy before the gas was split. Compare the temperatures of the gas. What is the difference between the internal energy of the ideal gas and its temperature?

d. Now imagine that the gas for which you know the internal energy is in a container that has two chambers separated by a removable divider. The left chamber has volume V and the gas is in that chamber. The chamber on the right has the same volume, but is completely empty – there is no gas there. Now you remove the divider and the gas that previously occupied volume V is now occupying volume $2V$. What happens to the energy of the gas?

OALG 15.1.2 Observe and explain

In the following video, you see a syringe and a piston that fits snugly into it. At the end of the piston is a small hook to which a small piece of cotton is tied. The experimenter is holding the syringe vertically and suddenly presses down forcefully on the piston. The high-speed video (recorded at 1200 frames per second) shows what happens:

[https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-1-2]. Answer the questions below:

a. What happens to the temperature of the air in the syringe during the experiment? How do you know?

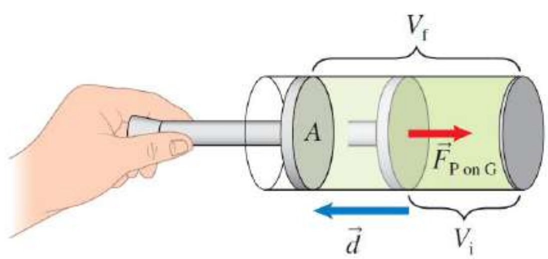
b. What happens to the pressure of the air in the syringe during the experiment? How do you know?

c. Draw an energy bar chart for the experiment. Choose the air in the syringe as a system. The initial state is before the piston is pushed in and the final is just before the cotton ball starts to burn.

OALG 15.1.3 Derive

In the previous activity, you learned that if you do work on a gas, you can increase its internal energy tremendously. But how do we calculate this work quantitatively?

Imagine that you have a gas (the system) at high pressure in a cylinder with a movable piston as shown in the figure below.



You hold the piston and allow it to move slowly outward to the left (if you were not holding it, the gas would push it out instantly). The gas pushes to the left on the piston and the piston in turn pushes toward the right on the gas, exerting a force on the gas $\vec{F}_{\text{P on G}}$. The gas expands slowly. What is the work done by the force that the piston exerts on the gas? Assume that the piston moves outward a distance d, allowing the gas to expand from its initial volume V_i to its final volume V_f, with the final volume being just slightly larger than the initial.

To derive the expression for the work, answer the following questions:

a. Recall the definition of work and when this definition is applicable.

b. Does the force that the piston exerts on the gas do work on the gas? Is the work positive or negative?

c. How can you represent this work mathematically?

d. Revise the expression you wrote in part **c**. to use pressure and volumes instead of force and distance. If you are having difficulties, consult the derivation in sub-section "Work done on a gas" in Section 15.1 in the textbook.

e. Represent this work on a graph of pressure versus volume.

OALG 15.1.4 Read and interrogate

Read and interrogate Section 15.1 in the textbook and compare the expression you derived for pressure with the expression in the book. Then answer Review Question 15.1.

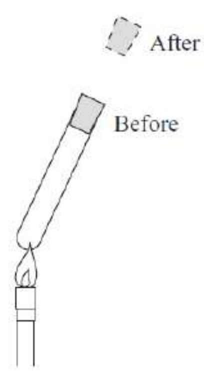
OALG 15.1.5 Practice

Answer Question 1-3 on page 471 and solve Problems 1, 4, and 5 on page 472 in the textbook.

15.2 Two ways to change the energy of a system

OALG 15.2.1 Observe and explain

Watch the video [https://youtu.be/u3Y4npFvlO4] Answer the following questions:



a. Construct a microscopic explanation for how the hot gas pushes out the stopper. Remember what you learned about molecules of gas, their motion, and the pressure that they exert.

b. Choose the gas inside the test tube, the stopper, and Earth (not the flame) as the system, and use the concepts of work and energy to explain the experiment. If you need a new physical quantity or quantities for your explanation, define them qualitatively.

c. Read and interrogate Section 15.2 in the textbook and compare the conclusions in this section with your answers to part **b** of this activity.

d. Draw an energy bar chart to explain the experiment using this new physical quantity. The system is the gas and the cork. The initial state is before we started warming up the gas and the final state is when the cork is flying out.

OALG 15.2.2 Observe and explain

Watch the video of a cup of cold water in an aluminum container being placed in a container with warm water [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-2-2]. The video is taken with a thermal camera and allows you to see the change of temperature of the water.

a. Describe what you observe (choose the initial state to be when the cup is outside the container and the final state when cup is inside and the temperature reaches some intermediate value).

b. Consider the water in the cup as the system and explain this observed process using your knowledge of molecules and their motion. Then use the generalized work–energy principle developed in Chapter 7 to explain what happened to the cold water. If you cannot explain this process with this principle, try to modify the principle (for example, introduce a new physical quantity) to account for your observations.

c. Repeat part **b.**, only this time consider the water in the container as the system.

d. Use your knowledge of molecules and their motion to explain the reasoning behind when two liquids of different temperatures mix together, the mixture will eventually reach some intermediate temperature (called the *equilibrium temperature*).

OALG 15.2.3 Observe and explain

Equipment: two pieces of paper.

Vigorously rub two pieces of paper together, pressing the fingers of each hand firmly on the paper as you rub it. Consider one piece of paper as the system. Why did the thermal energy of that piece of paper increase?

15.3 First law of thermodynamics

OALG 15.3.1 Observe and explain

Watch the video of a cup of glycerin being stirred by a mixer used to whip cream [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-3-1]. The video is taken with a thermal camera and allows you to follow the temperature of the glycerin at the spot marked by cross hairs.

a. Describe what you observe.

b. Draw a bar chart to represent the process. Indicate any assumptions that you made.

c. Answer Review Question 15.2 on page 448 in the textbook.

OALG 15.3.2 Explain

Try to use the generalized work–energy principle (without heating), written in the form $\left(U_{gi}+K_i\right)+W=\left(U_{gf}+K_f+\Delta U_{int}\right)$, to explain the following phenomena. If the principle accounts for the phenomenon, describe the work or energy changes in symbols or words. If it does not account for the phenomenon, describe the difficulty and see whether including heating $\left(U_{gi}+K_i\right)+W+Q=\left(U_{gf}+K_f+\Delta U_{int}\right)$ in the principle helps to account for your observations, where Q stands for heating. Be sure to indicate the system used in your analysis of each experiment and any assumptions that you made about the process or the system.

Verbal representation of the process	**Write a W/E word explanation (if possible).**	**Or write a $W/Q/E$ word explanation (if the left cell is not possible).**
Drop a golf ball from a window. The process begins at the instant the ball leaves your hand and ends just before it hits the grass below. The system is the golf ball and Earth.		
Drop a golf ball from a window. The process begins at the instant the ball leaves your hand and ends just after the ball stops in the grass below. The system is the golf ball, Earth, and the grass.		
Place a warm golf ball on top of a cube of ice. The process begins at the instant you place the ball on the ice cube and ends when the ice has melted and the ball has cooled. Choose the ice cube as the system.		
While walking on a golf course in the winter, you find a golf ball and slowly lift it from the frozen grass and place it in your pocket. The process starts with the ball at		

rest in the cold grass and ends 10 minutes later after it has warmed up in your pocket. Choose the ball and Earth as the system (you are not in the system).		

OALG 15.3.3 Explain

Use the generalized work–energy principle with heating, called the first law of thermodynamics $W + Q = \Delta E$, to explain the processes described below in words. Decide whether the gravitational and kinetic energies of the system change.

Verbal representation of the process	**Write an explanation in words using the terms of energy, heating, and work.**	**Indicate the signs of the** $W/Q/U_{int}$ **terms in the equation.**	**Represent the process with a bar chart.**
A gas, originally at 20.0 °C, resides in a cylinder with a movable piston. You push on the piston, thus compressing and warming the gas. The cylinder is insulated so that there is no thermal energy transfer into or out of the gas. Choose the gas in the cylinder as the system.		W: Q: ΔU_{int} :	
A gas, originally at 0.0 °C, resides in a cylinder with a movable piston, the cylinder is inside a bath filled with ice water. You push slowly on the piston, thus compressing the gas, but this time the gas does not warm up. The cylinder has thin metal walls and slightly warms the water surrounding it. Choose the gas in the cylinder as the system.		W: Q: ΔU_{int} :	
A burning match warms a paper cup that holds ice water. After 2 minutes of		W: Q:	

warming, the water is still at 0°C but now has less ice and more liquid water. Choose the ice water as the system.		ΔU_{int} :	

OALG 15.3.4 Explain

a. Compare and contrast the physical quantities of temperature, internal thermal energy, and heating. What is similar about them? What is different?

b. Why do we use the term "heating" instead of the term "heat"? If you have any difficulty answering this question, refer to Section 15.3 in the textbook for help.

OALG 15.3.5 Evaluate

Eugenia and Gorazd were traveling in New Zealand and bought some raspberry jam. Evaluate the text in red on the jam lid (see the photo at right below).

OALG 15.3.6 Read and interrogate

Read and interrogate Section 15.3 in the textbook and answer Review Question 15.3.

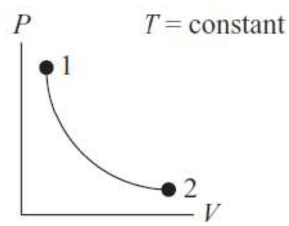
OALG 15.3.7 Practice

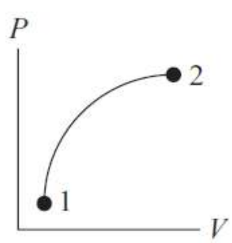
Answer Questions 8 and 11 on page 471 and solve Problems 7-10 on page 472 in the textbook.

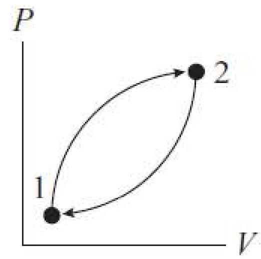
15.4 Applying the first law of thermodynamics to gas processes

OALG 15.4.1 Represent and reason

A graphical description of three processes for a gas in a container is provided in the table below (+ means a positive value and – a negative value). The gravitational and kinetic energies of the system do not change. Complete the table that follows. Note that the process in part **c**. is cyclic—the system returns to its starting state. For part **c**. you are to decide the changes in the three quantities for each part of the cycle (1 to 2 and 2 to 1) and for the complete cycle.

a.		
Describe the process in words.	Graphical description 	Was ΔU_{int} $+, -, 0$?
Was W $+, -, 0$? (Also indicate this on the graph in the graphical description.)	Was Q $+, -, 0$?	Explain each process by using your knowledge of the motion of molecules in an ideal gas.

b.		
Describe the process in words.	Graphical description 	Was ΔU_{int} $+, -, 0$?
Was W $+, -, 0$? (Also indicate this on the graph in the graphical description.)	Was Q $+, -, 0$?	Explain each process by using your knowledge of the motion of molecules in an ideal gas.

c.		
Describe the process in words.	Graphical description 	Was ΔU_{int} +,−,0? For $1 \rightarrow 2$: For $2 \rightarrow 1$: For $1 \rightarrow 2 \rightarrow 1$:
Was W +,−,0? (Also indicate this on the graph in the graphical description.) For $1 \rightarrow 2$: For $2 \rightarrow 1$: For $1 \rightarrow 2 \rightarrow 1$:	Was Q +,−,0? For $1 \rightarrow 2$: For $2 \rightarrow 1$: For $1 \rightarrow 2 \rightarrow 1$:	Explain each process by using your knowledge of the motion of molecules in an ideal gas. For $1 \rightarrow 2$: For $2 \rightarrow 1$: For $1 \rightarrow 2 \rightarrow 1$:

OALG 15.4.2 Represent and reason

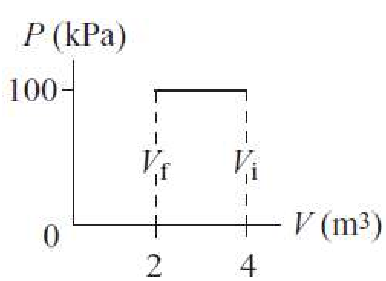
Answer the following questions about two gas processes represented with *P*-versus-*V* graphs:

a. Determine the work done on the system during each process.

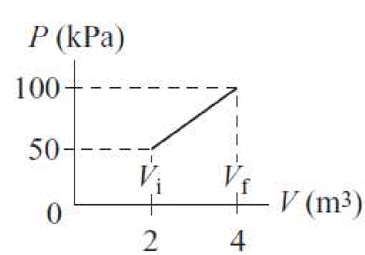
b. Describe a possible process in words.

c. Explain the process using your knowledge of gas particles.

1.

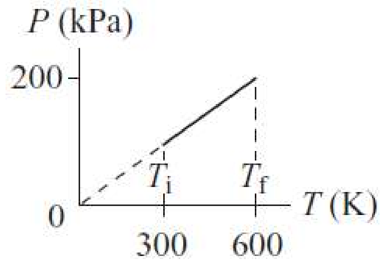
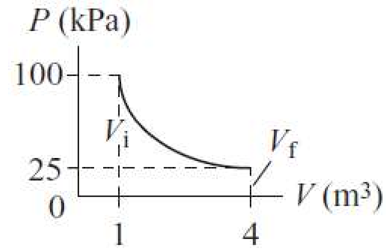
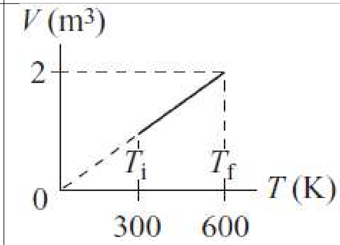


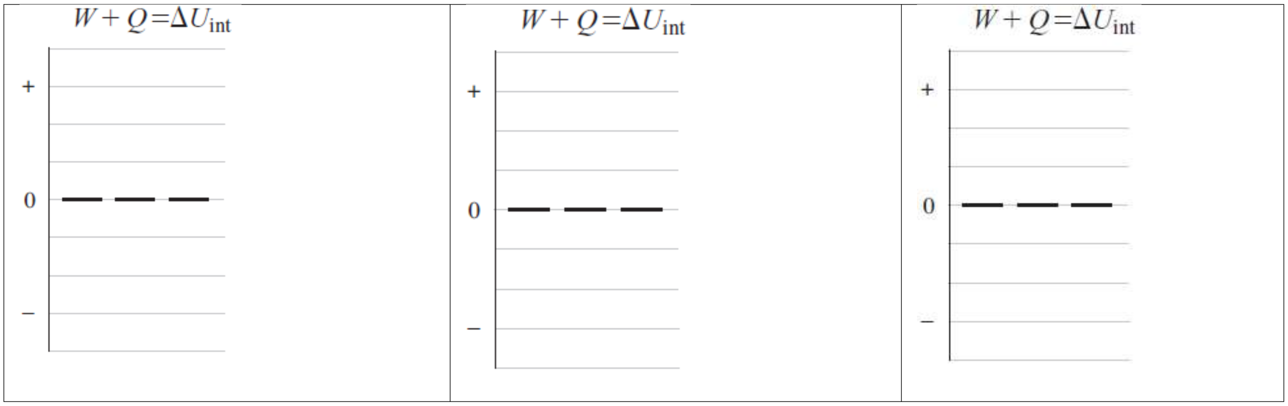
2.



OALG 15.4.3 Represent and reason

The first row of the table below graphically represents an isochoric (constant volume) process, an isothermal (constant temperature) process, and an isobaric (constant pressure) process. Each process involves 1.0 mol of an ideal gas. Complete the table for each process.

Isochoric process	Isothermal process	Isobaric process
		
Use the ideal gas law to calculate the volume of the gas. Then determine the work done by the environment on the gas during the process.	Use the ideal gas law to calculate the temperature of the 1.0 mol of gas. Then use the temperature to determine the *change* in the internal energy of the gas.	Use the ideal gas law to determine the gas pressure. Then determine the work done by the environment on the gas during the process.
Use the initial and final temperatures to determine the change in internal energy of the 1.0 mol of gas during the process.	Use the ideal gas law to write the pressure of the gas in terms of its volume (and other constant physical quantities).	Use the initial and final temperatures to determine the change in internal energy of the 1.0 mol of gas during the process.
Use these results to construct a qualitative work–heating–internal energy change bar chart for the process.	Use these results to construct a qualitative work–heating–internal energy change bar chart for the process.	Use these results to construct a qualitative work–heating–internal energy change bar chart for the process.



OALG 15.4.4 Regular problem

Solve this problem by following the steps of the problem-solving strategy and then compare your solution to the solution in Example 15.1 in the textbook.

A burner heats $1.0\ \text{m}^3$ of air inside a small hot air balloon. Initially, the air is at $37\ ^\circ\text{C}$ and atmospheric pressure. Estimate the amount of energy that needs to be transferred to the air through heating (in joules) to make it expand from a volume of $1.0\ \text{m}^3$ to $1.2\ \text{m}^3$. Indicate any assumptions that you made.

OALG 15.4.5 Explain

Is it possible for a gas to cool while you are transferring energy to it through heating? Explain your answer and give an example.

OALG 15.4.6 Read and interrogate

Read and interrogate Section 15.4 in the textbook and answer Review Question 15.4.

OALG 15.4.7 Practice

Answer Question 9 on page 471 and solve Problems 10-12 on page 472 and Problem 63 on page 474 in the textbook.

15.5 Specific heat

OALG 15.5.1 Observe and find a pattern

You have a small electric heater and water in a calorimeter (an insulated container). The amount of energy provided to the system and the change in water temperature are shown below.

t (s)	ΔU (J)	ΔT (°C) $= T_f - T_i$
0	0	0.0
10	1000	2.4
20	2000	4.8
30	3000	7.2
40	4000	9.6
50	5000	12.0
60	6000	14.4

a. Graph the data in the table to decide whether there is a relationship between the amount of energy provided to the system (the water) and its temperature change ΔT. Think about which physical quantity is the independent variable and which physical quantity is the dependent variable.

b. Write the mathematical relationship.

OALG 15.5.2 Observe and find a pattern

In a second set of experiments, recorded in the table below, the same amount of energy (4000 J) is provided to identical insulated water containers, which contain different masses of water.

m (kg)	ΔT(°C)
0.10	9.6
0.20	4.8
0.30	3.2
0.40	2.4

a. Graph the data and decide whether there is a mathematical relationship between the change in temperature and the mass of water (the system) when the amount of energy provided is the same.

b. Write the mathematical relationship.

OALG 15.5.3 Observe and find a pattern

The same amount of energy (4000 J) is provided to four identical-mass (1 kg) systems with different substances. What can you conclude based on the data in the table below? Can we say that the density of the liquid determines how much its temperature changes when a certain amount of energy is provided? If not, then what property of liquids will determine the change in its temperature given a certain amount of energy is provided?

Substance	**ΔT(°C)**
Freshwater	0.95
Seawater	1.03
Alcohol	1.65
Mercury	28.47

OALG 15.5.4 Reason

a. In Activity 15.5.1 you found a relationship between the amount of energy provided to the system and the temperature change (for constant mass), and in Activity 15.5.2 a relationship between the mass and the temperature change. You also found that the same amount of energy provided to different types of materials caused different temperature changes. Combine these results by writing a mathematical representation that shows how the change in temperature ΔT of a system depends on the amount of energy provided, ΔU, the system's mass *m*, and the particular type of material of that system. You can account for the type of material by using a new quantity *c* (called the specific heat of that particular type of material) measured in J/(kg · °C). Be sure that the units in your new mathematical representation are consistent.

b. Compare and contrast the mathematical representation that you devised with Equation 15.5 in the textbook.

OALG 15.5.5 Design an experiment

Equipment: immersion heater, thermometer, container for water, measuring cup.

Examine the water heater and note its stated power rating. Design and conduct an experiment to test whether the manufacturer provided an accurate rating.

a. Brainstorm experiments that you can carry out and then describe an experiment that you agree to perform to test the power rating.

b. Draw a picture of the experimental set-up. Include physical quantities that you will measure and calculations you will make.

c. Complete the calculations to predict the outcome of the experiment.

d. List assumptions and how each will affect the result. List experimental uncertainties and how they will affect the result.

e. Perform the experiment; record the outcome of the experiment, and decide whether the manufacturer's rating is reasonable.

If you do not have an immersion water heater, use the following data for your analysis:

1 liter of water is boiled from 15 C to 100 C in 388s.

The label on the heater states: 990-1100W.

OALG 15.5.6 Analyze

Watch the video of a cup of glycerin being stirred by a mixer used to whip cream [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-5-7]. The video is taken with a thermal camera and allows you to follow the temperature of the glycerin at the location of the cross hairs.

a. Use the data provided in the video to estimate how much energy provided by the mixer went into warming up the glycerin.

b. Could this experiment be used to test the equivalence of work and heating as a means for energy transfer similar to the historical experiment performed by James Joule? Explain why or why not. This historical experiment is described in Testing Experiment Table 15.2 in the textbook.

OALG 15.5.7 Read and interrogate

Read and interrogate Section 15.5 in the textbook and answer Review Question 15.5.

OALG 15.5.8 Practice

Answer Questions 5 and 6 on page 471 and solve Problems 13, 19, and 20 – 23 on pages 471-473 in the textbook.

15.6 Changing state

OALG 15.6.1 Explain

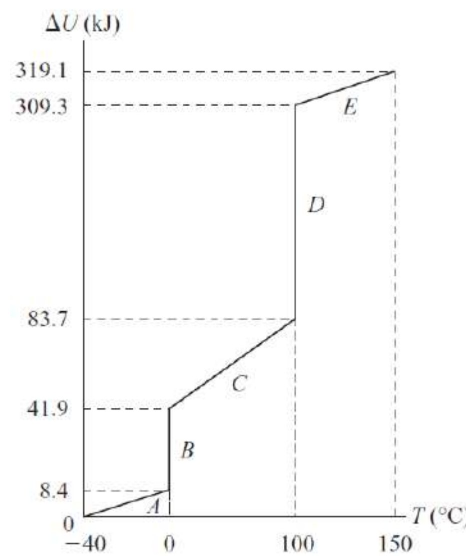
Water in a pan is at its boiling temperature (about 100 °C). A gas flame continues to make contact with the pan holding the water, and after some time, all of the water has boiled away. The water vapor is at about the same temperature as the water at its boiling point (about 100 °C).

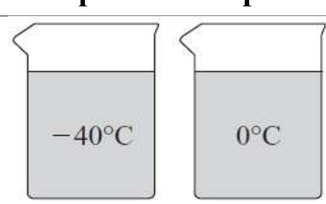
a. Consider the water as the system and explain this process using your knowledge of work and energy. If you need any new physical quantity for your explanation, define it qualitatively.

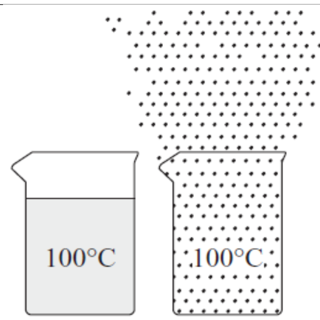
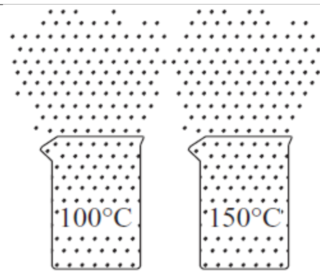
b. After contact with the flame for some time interval, the pan, liquid water, and water vapor were at about the same temperature. On a molecular level, what happened to the energy transferred from the hot flame to the water?

OALG 15.6.2 Represent and reason

A process with five parts is shown in the graph at right. Carefully examine the following table, which represents the parts of the process in multiple ways—words, sketches, a graph, and a mathematical representation. The process starts with 0.10 kg of ice at $-40\ °\text{C}$ and ends with 0.10 kg of steam at $+150\ °\text{C}$. *Note: c* stands for specific heat and ΔU for the change in internal energy.



Words	**Sketch the initial and final parts of the process.**	**Mathematical rperesentation**
A. Ice starts at –40 °C and warms to its melting temperature at 0 °C.		$\Delta U_A = mc_{\text{solid}}\left[T_{\text{melt}} - \left(-40°\text{C}\right)\right]$
B. Energy provided to the ice causes the solid ice to convert slowly to liquid at $0\ °\text{C}$.		$\Delta U_B = +mL_{\text{f}}$

C. After the ice has completely melted, more energy causes the liquid water to warm from 0 °C to 100 °C, its boiling temperature.		$\Delta U_C = mc_{\text{liquid}}\left(T_{\text{boil}} - T_{\text{melt}}\right)$
D. Now, energy provided causes the water to convert slowly from the liquid to the gaseous state while still at 100 °C.		$\Delta U_D = +mL_{\text{v}}$
E. Additional energy causes the gas to warm from 100 °C to 150 °C.		$\Delta U_E = mc_{\text{gas}}\left(150°\text{C} - T_{\text{boil}}\right)$

a. Are the mathematical representations for parts B and D consistent with the corresponding parts of the graph? Explain.

b. Consider the so-called state changes that occur when ice is melting from a solid to a liquid in part B and evaporating from a liquid to a gas in part D. What happens to the temperature of the matter during these state-change processes? Explain.

c. Explain microscopically what is needed in terms of energy for parts B and D—that is, to convert the solid water to liquid water and then to convert the liquid water to gaseous water.

d. Compare your answers to part **c** with the answers in Section 15.6 in the textbook.

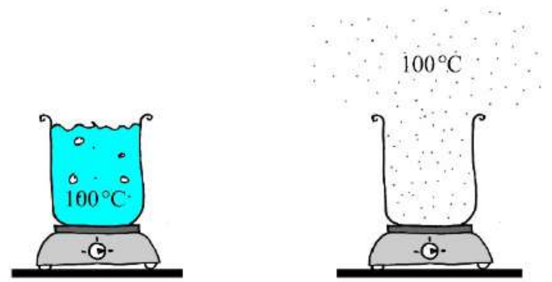
OALG 15.6.3 Reason

Use the information in the graph in Activity 15.6.2 to determine the heat capacity for the solid, the liquid, and the gaseous phases of water and its latent heats of fusion and vaporization.

OALG 15.3.4 Explain

Equipment: hot plate, container with boiling water

You have one liter of water at $100\ ^\circ\mathrm{C}$. In order to change this water into steam at $100\ ^\circ\mathrm{C}$, the stove needs to transfer $2.3\ \mathrm{MJ}$ of energy by heating to the water. Where does this energy go?



Consider the following two explanations:

(1) Energy added by heating is equal to the negative work done by the system (water molecules) on the environment (air at atmospheric pressure) as the vapor expands.

(2) Energy added by heating is equal to the increase of the potential energy of interaction of the water molecules (energy due to attractive forces between the molecules).

a. Use your knowledge of the ideal gas law and work done by gases to show which explanation is better.

b. Let us assume that the total potential energy of interaction of the water molecules when they are infinitely far apart (the state of ideal gas) is zero. Represent the process shown above using work-heating-energy bar charts. Represent the potential energy of the molecules with a symbol $U_{\text{attractive}}$ and the thermal energy of the molecules as the kinetic energy.

OALG 15.6.5 Represent and reason

Word descriptions for three processes are provided. Fill in the table that follows by describing each process with a pictorial representation (including the initial and final states and what happens to each type of matter in going from the initial state to the final state). Then apply the first law of thermodynamics. Do not solve for anything.

Word description	**Sketch and translate; include the changes in going from the initial to the final state.**	**Write simplifying assumptions.**	**Represent mathematically in symbols (apply the temperature-change and state-change mathematical representations).**
A 50-g metal spoon at temperature $20\ ^\circ\mathrm{C}$ is placed in an insulated			

cup with 200 g of coffee at 100 °C. The spoon and coffee reach a final temperature T_f.			
25 g of 10 °C milk is added to 200 g of 70 °C coffee in an insulated cup. The coffee and milk reach a final temperature T_f.			
A 200-g aluminum block at +150 °C is placed in a large insulated cup with 40 g of ice at −10 °C. The aluminum and ice reach a final temperature T_f (the ice has completely melted).			

OALG 15.6.6 Equation Jeopardy

Each of the mathematical representations below describes a thermodynamics process. Describe each process in words.

a. $Q = (0.40\text{ kg})(4186\text{ J/kg}\cdot°\text{C})(100\text{ °C} - 30\text{ °C}) + (0.10\text{ kg})(2.56\times10^6\text{ J/kg})$

b. $(0.40\text{ kg})(2090\text{ J/kg}\cdot°\text{C})[0\text{ °C} - (-8\text{ °C})] + (0.40\text{ kg})(33.3\times10^4\text{ J/kg})$
$+ (0.40\text{ kg})(4186\text{ J/kg}\cdot°\text{C})(T_f - 0\text{ °C}) + (2.0\text{ kg})(4186\text{ J/kg}\cdot°\text{C})(T_f - 50\text{ °C}) = 0$

OALG 15.6.7 Apply

Watch the video of a 0.3-kg ice-water mixture being put on a constant power stove [https://youtu.be/hLcYCzMgSzc]. The video shows thermal images recorded at consecutive time intervals. Thermal images allow us to determine the surface temperature of the objects. In the video, the temperature is measured at the spot on the metal pot (marked with a cross) and displayed in degrees Celsius.
a. Explain the graph shown at the end of the video.

b. Use the graph and other data to estimate the power of the heater. Indicate any assumptions that you made.

OALG 15.6.8 Read and interrogate

Read and interrogate Section 15.6 and answer Review Question 15.6.

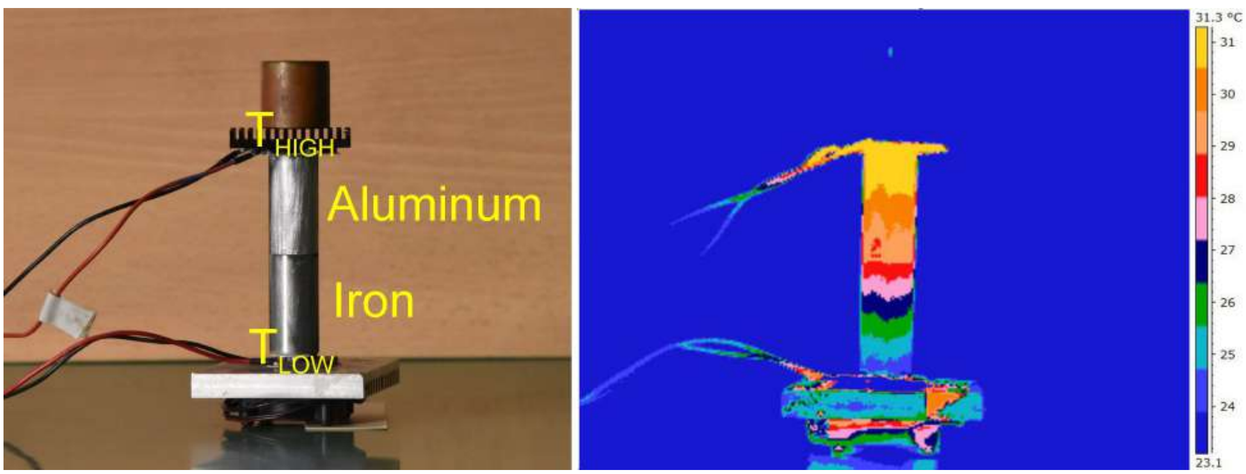
OALG 15.6.9 Practice

Answer Questions 12-15 on page 471 and solve Problems 29 – 32 on page 473 in the textbook.

15.7 Heating mechanisms

OALG 15.7.1 Observe and explain

Examine the photos below. The photo on the left is taken with a regular camera and it shows the set-up of the experiment. The photo on the right is taken with a thermal camera and allows you to observe the surface temperatures of different parts of the set up (colors indicate $1\ ^{\circ}\mathrm{C}$-temperature intervals (also see the color coding on the right of the photo)). The T_{high} and T_{low} labels indicate the temperatures that are kept constant during the experiment. Carefully examine the photo on the right.

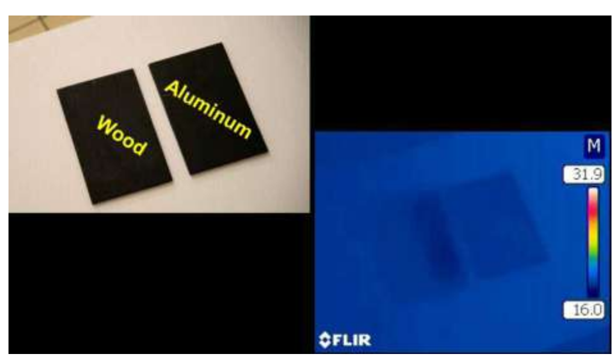


a. Describe what you observe.

b. Explain what you observe.

OALG 15.7.2 Observe and explain

Observe the video of an experiment taken with a regular camera and a thermal camera [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-2]. In the experiment, two identical metal objects (made of brass) are taken from the same hot water bath



and placed on two identically-shaped (same height, length, and width) plates. The plates are made of wood and aluminum (colored with the same black paint to reduce the reflective properties of aluminum) and have been sitting on the table for a long time.

a. Describe what you observe.

b. Devise one or more explanations for your observation.

OALG 15.7.3 Test your ideas

You use the same plates as in Activity 15.7.2, but this time you place an ice cube on each one.

a. Use the explanations you made in Activity 15.7.2 to predict what you will observe.

b. View the video [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-3] and compare the outcome to your predictions. Do you need to revise your explanation?

OALG 15.7.4 Observe and explain

Observe the video of an experiment taken with a thermal camera [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-4]. In the experiment, you have two identical pieces of paper, one wet with water (on the right) and the other wet with acetone (on the left).

a. Describe what you observe. Make sure you watch the video until the end.

b. Explain your observation. Make sure you use your knowledge from the first section of Chapter 12.

OALG 15.7.5 Observe and explain

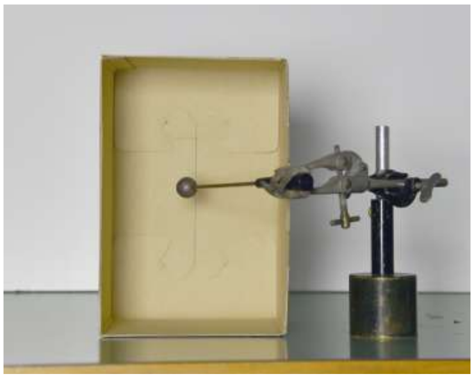
a. Observe the video of the experiment [https://mediaplayer.pearsoncmg.com/assets/_frames.true/sci-phys-egv2e-alg-15-7-5] and describe what you observe.

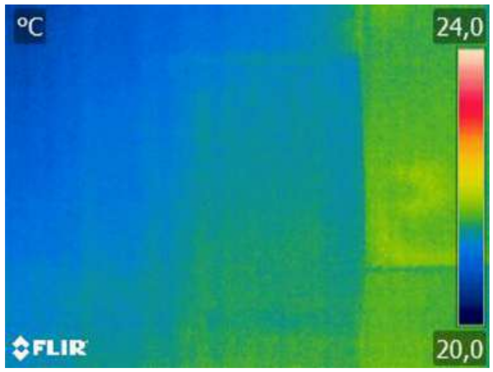
b. Explain why the position of the ice cube affects whether or not it melts.

c. Now, examine the photo in Activity 15.7.1 and explain why the experimenters placed the hot temperature part of the device at the top and the cold temperature part of the device at the bottom.

OALG 15.7.6 Observe and explain

The figures below show the experimental setup (figure on the left) and the thermal image of the same setup (figure on the right). The setup consists of a cardboard box and a metal sphere on a stand. The thermal image shows the surface temperature of the objects. The temperatures in the thermal images in this activity are represented with colors in the interval from 20 °C (dark blue) to 34 °C (white).



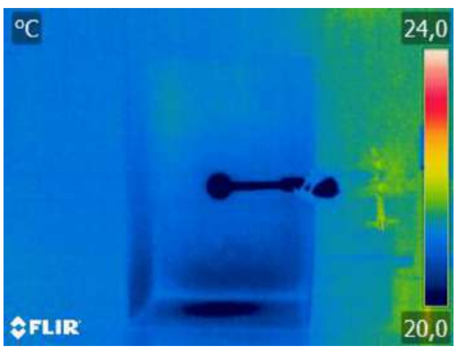


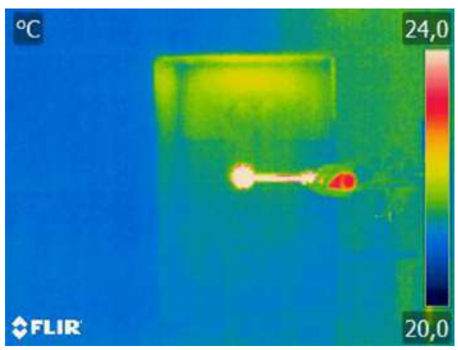
The experimenter performed the following two experiments:

Experiment 1: She heated the metal sphere so that it reached a temperature of 80 ° C, placed the sphere as shown above, waited for about 30 s and took the thermal image.

Experiment 2: She cooled the metal sphere so that it reached the temperature of -5 ° C, placed the sphere as shown above, waited for about 30 s and took the thermal image.

a. Below are the two thermal images. Which was obtained in Experiment 1 and which was obtained in Experiment 2? Explain how you know. Describe and explain any other details that you notice about the images.





OALG 15.7.6 Read and interrogate

Read and interrogate Section 15.7 and answer Review Question 15.7.

OALG 17.7.7 Practice

Answer Questions 10, 17, and 22-25 on page 471 and solve Problems 43, 59, and 69 on pages 473 – 474 in the textbook.

