- When a change of phase occurs, the temperature does not change.
- The heat of vaporization of a substance is equal to the amount of energy needed to change the substance from a liquid to a gas (or from a gas to a liquid).
- The heat of fusion of a substance is equal to the amount of energy needed to change the substance from a solid to a liquid (or from a liquid to a solid).

Practice Exercises

In each case, select the choice that best answers the question or completes the statement. Use Appendix IV for reference.

1. Four thousand joules of heat are added to 100 grams of water when its temperature is 40°C. The new temperature of the water is approximately
(A) 30°C
(B) 45°C
(C) 50°C
(D) 60°C
(E) 70°C

2. If 2 kilojoules of heat are added to 500 grams of water at 100°C and standard pressure, after 2 minutes the temperature of the water will be
(A) 100°C
(B) 110°C
(C) 115°C
(D) 120°C
(E) 125°C

3. A girl has 240 grams of water at 50°C. How many grams of ice, at 0°C, are needed to cool the water to 0°C?
(A) 35
(B) 150
(C) 250
(D) 500
(E) 750

4. A certain alloy has a melting point of 1,000°C. The specific heat of the solid is 1.257 joules per gram · C, and its heat of fusion is 84 joules per gram. Approximately how many kilojoules of heat are required to change 10 grams of the material from a solid at 20°C to a liquid at 1,000°C?
(A) 5.6
(B) 8.2
(C) 13.2
(D) 15.7
(E) 20

5. As the temperature of a solid increases, its specific heat
(A) increases
(B) decreases

(C) increases, then decreases
(D) decreases, then increases
(E) remains the same

6. When 1 gram of atmospheric water vapor condenses in the air, it results in
(A) always cooling the surrounding air
(B) always heating the surrounding air
(C) always leaving the surrounding air temperature unchanged
(D) heating the surrounding air only if the change occurs below 100°C
(E) cooling the surrounding air only if the change occurs below 100°C

7. Approximately how much heat energy (in kilojoules) is required to raise the temperature of 200 grams of lead from its melting point to its boiling point?
(A) 28
(B) 45
(C) 31
(D) 37
(E) 53

8. How much heat energy is required to completely vaporize 2 kilograms of alcohol at its boiling point?
(A) 855 kJ
(B) 109 kJ
(C) 1,710 kJ
(D) 218 kJ
(E) 2.43 kJ

9. Which of the following substances is a liquid at 150°C and standard air pressure?
(A) Mercury
(B) Alcohol
(C) Zinc
(D) Ammonia
(E) Water

Answer Key

1. **(C)**	4. **(C)**	7. **(D)**
2. **(A)**	5. **(E)**	8. **(C)**
3. **(B)**	6. **(B)**	9. **(A)**

Answers Explained

1. **C** Heat gained = mass × sp. ht. × temp. change.
4,000 J = 100 g × 4.19 kJ/kg · °C × temp. change. Temp. change = 9.5°C.

Therefore, new temperature = 49.5°C or approximately 50°C.

2. **A** At its boiling point, the temperature of the water remains the same, 100°C.

3. **B** The heat lost by the water is transferred to the melting ice at 0°C:

$$(240\text{ g}) \times (4.19\text{ kJ/kg} \cdot {}^\circ\text{C}) \times (50^\circ\text{C}) = \text{mass} \times (335\text{ J/g})$$
$$\text{mass of ice} = 150\text{ g}$$

4. **C** Heat gained = (mass × sp. ht. × temp. change) + (mass × heat of fusion)
Heat gained = (10 g) × (1.257 J/g · °C) × (980°C) + (10 g) × (84 J/g)
Heat gained = 13,158.6 J, which is approximately equal to 13.2 kJ

5. **E** The specific heat of a substance remains constant in the solid state.

6. **B** Heat is required to vaporize a liquid. Whenever the vapor condenses to a liquid, heat has to be given off again to the surroundings. In this case the condensation results in heating the surrounding air.

7. **D** Heat gained = mass (in kg) × sp. ht. × change in temperature.
Heat gained (in kJ) = (0.2 kg) × (0.13 kJ/kg · °C) × (1,412°C)
= 36.7 kJ or 37 kJ.

8. **C** From Appendix IV, we see that the heat of vaporization of alcohol is 855 kJ/kg. The total amount of heat needed to vaporize the alcohol completely is the product of its mass and heat of vaporization:
heat (in kJ) = mass (in kg) × (heat of vaporization)
heat = (2 kg) × (855 kJ/kg) = 1,710 kJ

9. **A** From the list of boiling points in Appendix IV, we see that only mercury remains a liquid at 150°C.

Problems & Exercises

13.1 Temperature

1. What is the Fahrenheit temperature of a person with a 39.0°C fever?

2. Frost damage to most plants occurs at temperatures of 28.0°F or lower. What is this temperature on the Kelvin scale?

3. To conserve energy, room temperatures are kept at 68.0°F in the winter and 78.0°F in the summer. What are these temperatures on the Celsius scale?

4. A tungsten light bulb filament may operate at 2900 K. What is its Fahrenheit temperature? What is this on the Celsius scale?

5. The surface temperature of the Sun is about 5750 K. What is this temperature on the Fahrenheit scale?

6. One of the hottest temperatures ever recorded on the surface of Earth was 134°F in Death Valley, CA. What is this temperature in Celsius degrees? What is this temperature in Kelvin?

7. (a) Suppose a cold front blows into your locale and drops the temperature by 40.0 Fahrenheit degrees. How many degrees Celsius does the temperature decrease when there is a 40.0°F decrease in temperature? (b) Show that any change in temperature in Fahrenheit degrees is nine-fifths the change in Celsius degrees.

8. (a) At what temperature do the Fahrenheit and Celsius scales have the same numerical value? (b) At what temperature do the Fahrenheit and Kelvin scales have the same numerical value?

13.2 Thermal Expansion of Solids and Liquids

9. The height of the Washington Monument is measured to be 170 m on a day when the temperature is 35.0°C. What will its height be on a day when the temperature falls to -10.0°C? Although the monument is made of limestone, assume that its thermal coefficient of expansion is the same as marble's.

10. How much taller does the Eiffel Tower become at the end of a day when the temperature has increased by 15°C? Its original height is 321 m and you can assume it is made of steel.

11. What is the change in length of a 3.00-cm-long column of mercury if its temperature changes from 37.0°C to 40.0°C, assuming the mercury is unconstrained?

12. How large an expansion gap should be left between steel railroad rails if they may reach a maximum temperature 35.0°C greater than when they were laid? Their original length is 10.0 m.

13. You are looking to purchase a small piece of land in Hong Kong. The price is "only" $60,000 per square meter! The land title says the dimensions are $20\text{ m}\times 30\text{ m}.$ By how much would the total price change if you measured the parcel with a steel tape measure on a day when the temperature was 20°C above normal?

14. Global warming will produce rising sea levels partly due to melting ice caps but also due to the expansion of water as average ocean temperatures rise. To get some idea of the size of this effect, calculate the change in length of a column of water 1.00 km high for a temperature increase of $1.00^{\circ}\text{C}.$ Note that this calculation is only approximate because ocean warming is not uniform with depth.

15. Show that 60.0 L of gasoline originally at 15.0°C will expand to 61.1 L when it warms to $35.0^{\circ}\text{C},$ as claimed in **Example 13.4**.

16. (a) Suppose a meter stick made of steel and one made of invar (an alloy of iron and nickel) are the same length at 0°C. What is their difference in length at 22.0°C? (b) Repeat the calculation for two 30.0-m-long surveyor's tapes.

17. (a) If a 500-mL glass beaker is filled to the brim with ethyl alcohol at a temperature of $5.00^{\circ}\text{C},$ how much will overflow when its temperature reaches 22.0°C? (b) How much less water would overflow under the same conditions?

18. Most automobiles have a coolant reservoir to catch radiator fluid that may overflow when the engine is hot. A radiator is made of copper and is filled to its 16.0-L capacity when at $10.0^{\circ}\text{C}.$ What volume of radiator fluid will overflow when the radiator and fluid reach their 95.0°C operating temperature, given that the fluid's volume coefficient of expansion is $\beta = 400\times 10^{-6}/{}^{\circ}\text{C}$? Note that this coefficient is approximate, because most car radiators have operating temperatures of greater than $95.0^{\circ}\text{C}.$

19. A physicist makes a cup of instant coffee and notices that, as the coffee cools, its level drops 3.00 mm in the glass cup. Show that this decrease cannot be due to thermal contraction by calculating the decrease in level if the 350 cm^3 of coffee is in a 7.00-cm-diameter cup and decreases in temperature from 95.0°C to $45.0^{\circ}\text{C}.$ (Most of the drop in level is actually due to escaping bubbles of air.)

20. (a) The density of water at 0°C is very nearly 1000 kg/m^3 (it is actually 999.84 kg/m^3), whereas the density of ice at 0°C is 917 kg/m^3. Calculate the pressure necessary to keep ice from expanding when it freezes, neglecting the effect such a large pressure would have on the freezing temperature. (This problem gives you only an indication of how large the forces associated with freezing water might be.) (b) What are the implications of this result for biological cells that are frozen?

21. Show that $\beta \approx 3\alpha,$ by calculating the change in volume ΔV of a cube with sides of length $L.$

13.3 The Ideal Gas Law

22. The gauge pressure in your car tires is $2.50\times 10^5\text{ N/m}^2$ at a temperature of 35.0°C when you drive it onto a ferry boat to Alaska. What is their gauge pressure later, when their temperature has dropped to -40.0°C?

23. Convert an absolute pressure of $7.00\times10^5\ \text{N/m}^2$ to gauge pressure in lb/in^2. (This value was stated to be just less than $90.0\ \text{lb/in}^2$ in **Example 13.9**. Is it?)

24. Suppose a gas-filled incandescent light bulb is manufactured so that the gas inside the bulb is at atmospheric pressure when the bulb has a temperature of 20.0°C. (a) Find the gauge pressure inside such a bulb when it is hot, assuming its average temperature is 60.0°C (an approximation) and neglecting any change in volume due to thermal expansion or gas leaks. (b) The actual final pressure for the light bulb will be less than calculated in part (a) because the glass bulb will expand. What will the actual final pressure be, taking this into account? Is this a negligible difference?

25. Large helium-filled balloons are used to lift scientific equipment to high altitudes. (a) What is the pressure inside such a balloon if it starts out at sea level with a temperature of 10.0°C and rises to an altitude where its volume is twenty times the original volume and its temperature is -50.0°C? (b) What is the gauge pressure? (Assume atmospheric pressure is constant.)

26. Confirm that the units of nRT are those of energy for each value of R: (a) $8.31\ \text{J/mol}\cdot\text{K}$, (b) $1.99\ \text{cal/mol}\cdot\text{K}$, and (c) $0.0821\ \text{L}\cdot\text{atm/mol}\cdot\text{K}$.

27. In the text, it was shown that $N/V = 2.68\times10^{25}\ \text{m}^{-3}$ for gas at STP. (a) Show that this quantity is equivalent to $N/V = 2.68\times10^{19}\ \text{cm}^{-3}$, as stated. (b) About how many atoms are there in one μm^3 (a cubic micrometer) at STP? (c) What does your answer to part (b) imply about the separation of atoms and molecules?

28. Calculate the number of moles in the 2.00-L volume of air in the lungs of the average person. Note that the air is at 37.0°C (body temperature).

29. An airplane passenger has $100\ \text{cm}^3$ of air in his stomach just before the plane takes off from a sea-level airport. What volume will the air have at cruising altitude if cabin pressure drops to $7.50\times10^4\ \text{N/m}^2$?

30. (a) What is the volume (in km^3) of Avogadro's number of sand grains if each grain is a cube and has sides that are 1.0 mm long? (b) How many kilometers of beaches in length would this cover if the beach averages 100 m in width and 10.0 m in depth? Neglect air spaces between grains.

31. An expensive vacuum system can achieve a pressure as low as $1.00\times10^{-7}\ \text{N/m}^2$ at 20°C. How many atoms are there in a cubic centimeter at this pressure and temperature?

32. The number density of gas atoms at a certain location in the space above our planet is about $1.00\times10^{11}\ \text{m}^{-3}$, and the pressure is $2.75\times10^{-10}\ \text{N/m}^2$ in this space. What is the temperature there?

33. A bicycle tire has a pressure of $7.00\times10^5\ \text{N/m}^2$ at a temperature of 18.0°C and contains 2.00 L of gas. What will its pressure be if you let out an amount of air that has a volume of $100\ \text{cm}^3$ at atmospheric pressure? Assume tire temperature and volume remain constant.

34. A high-pressure gas cylinder contains 50.0 L of toxic gas at a pressure of $1.40\times10^7\ \text{N/m}^2$ and a temperature of 25.0°C. Its valve leaks after the cylinder is dropped. The cylinder is cooled to dry ice temperature (-78.5°C) to reduce the leak rate and pressure so that it can be safely repaired. (a) What is the final pressure in the tank, assuming a negligible amount of gas leaks while being cooled and that there is no phase change? (b) What is the final pressure if one-tenth of the gas escapes? (c) To what temperature must the tank be cooled to reduce the pressure to 1.00 atm (assuming the gas does not change phase and that there is no leakage during cooling)? (d) Does cooling the tank appear to be a practical solution?

35. Find the number of moles in 2.00 L of gas at 35.0°C and under $7.41\times10^7\ \text{N/m}^2$ of pressure.

36. Calculate the depth to which Avogadro's number of table tennis balls would cover Earth. Each ball has a diameter of 3.75 cm. Assume the space between balls adds an extra 25.0% to their volume and assume they are not crushed by their own weight.

37. (a) What is the gauge pressure in a 25.0°C car tire containing 3.60 mol of gas in a 30.0 L volume? (b) What will its gauge pressure be if you add 1.00 L of gas originally at atmospheric pressure and 25.0°C? Assume the temperature returns to 25.0°C and the volume remains constant.

38. (a) In the deep space between galaxies, the density of atoms is as low as $10^6\ \text{atoms/m}^3$, and the temperature is a frigid 2.7 K. What is the pressure? (b) What volume (in m^3) is occupied by 1 mol of gas? (c) If this volume is a cube, what is the length of its sides in kilometers?

13.4 Kinetic Theory: Atomic and Molecular Explanation of Pressure and Temperature

39. Some incandescent light bulbs are filled with argon gas. What is v_{rms} for argon atoms near the filament, assuming their temperature is 2500 K?

40. Average atomic and molecular speeds (v_{rms}) are large, even at low temperatures. What is v_{rms} for helium atoms at 5.00 K, just one degree above helium's liquefaction temperature?

41. (a) What is the average kinetic energy in joules of hydrogen atoms on the 5500°C surface of the Sun? (b) What is the average kinetic energy of helium atoms in a region of the solar corona where the temperature is $6.00\times10^5\ \text{K}$?

42. The escape velocity of any object from Earth is 11.2 km/s. (a) Express this speed in m/s and km/h. (b) At what temperature would oxygen molecules (molecular mass is equal to 32.0 g/mol) have an average velocity v_{rms} equal to Earth's escape velocity of 11.1 km/s?

43. The escape velocity from the Moon is much smaller than from Earth and is only 2.38 km/s. At what temperature would hydrogen molecules (molecular mass is equal to 2.016 g/mol) have an average velocity v_{rms} equal to the Moon's escape velocity?

44. Nuclear fusion, the energy source of the Sun, hydrogen bombs, and fusion reactors, occurs much more readily when the average kinetic energy of the atoms is high—that is, at high temperatures. Suppose you want the atoms in your fusion experiment to have average kinetic energies of $6.40\times10^{-14}\ \text{J}$. What temperature is needed?

45. Suppose that the average velocity (v_{rms}) of carbon dioxide molecules (molecular mass is equal to 44.0 g/mol) in a flame is found to be $1.05\times10^{5}\ \text{m/s}$. What temperature does this represent?

46. Hydrogen molecules (molecular mass is equal to 2.016 g/mol) have an average velocity v_{rms} equal to 193 m/s. What is the temperature?

47. Much of the gas near the Sun is atomic hydrogen. Its temperature would have to be $1.5\times10^{7}\ \text{K}$ for the average velocity v_{rms} to equal the escape velocity from the Sun. What is that velocity?

48. There are two important isotopes of uranium— ^{235}U and ^{238}U; these isotopes are nearly identical chemically but have different atomic masses. Only ^{235}U is very useful in nuclear reactors. One of the techniques for separating them (gas diffusion) is based on the different average velocities v_{rms} of uranium hexafluoride gas, UF_6. (a) The molecular masses for $^{235}\text{U}\ \ \text{UF}_6$ and $^{238}\text{U}\ \ \text{UF}_6$ are 349.0 g/mol and 352.0 g/mol, respectively. What is the ratio of their average velocities? (b) At what temperature would their average velocities differ by 1.00 m/s? (c) Do your answers in this problem imply that this technique may be difficult?

13.6 Humidity, Evaporation, and Boiling

49. Dry air is 78.1% nitrogen. What is the partial pressure of nitrogen when the atmospheric pressure is $1.01\times10^{5}\ \text{N/m}^2$?

50. (a) What is the vapor pressure of water at 20.0°C? (b) What percentage of atmospheric pressure does this correspond to? (c) What percent of 20.0°C air is water vapor if it has 100% relative humidity? (The density of dry air at 20.0°C is $1.20\ \text{kg/m}^3$.)

51. Pressure cookers increase cooking speed by raising the boiling temperature of water above its value at atmospheric pressure. (a) What pressure is necessary to raise the boiling point to 120.0°C? (b) What gauge pressure does this correspond to?

52. (a) At what temperature does water boil at an altitude of 1500 m (about 5000 ft) on a day when atmospheric pressure is $8.59\times10^{4}\ \text{N/m}^2$? (b) What about at an altitude of 3000 m (about 10,000 ft) when atmospheric pressure is $7.00\times10^{4}\ \text{N/m}^2$?

53. What is the atmospheric pressure on top of Mt. Everest on a day when water boils there at a temperature of 70.0°C?

54. At a spot in the high Andes, water boils at 80.0°C, greatly reducing the cooking speed of potatoes, for example. What is atmospheric pressure at this location?

55. What is the relative humidity on a 25.0°C day when the air contains $18.0\ \text{g/m}^3$ of water vapor?

56. What is the density of water vapor in g/m^3 on a hot dry day in the desert when the temperature is 40.0°C and the relative humidity is 6.00%?

57. A deep-sea diver should breathe a gas mixture that has the same oxygen partial pressure as at sea level, where dry air contains 20.9% oxygen and has a total pressure of $1.01\times10^{5}\ \text{N/m}^2$. (a) What is the partial pressure of oxygen at sea level? (b) If the diver breathes a gas mixture at a pressure of $2.00\times10^{6}\ \text{N/m}^2$, what percent oxygen should it be to have the same oxygen partial pressure as at sea level?

58. The vapor pressure of water at 40.0°C is $7.34\times10^{3}\ \text{N/m}^2$. Using the ideal gas law, calculate the density of water vapor in g/m^3 that creates a partial pressure equal to this vapor pressure. The result should be the same as the saturation vapor density at that temperature $(51.1\ \text{g/m}^3)$.

59. Air in human lungs has a temperature of 37.0°C and a saturation vapor density of $44.0\ \text{g/m}^3$. (a) If 2.00 L of air is exhaled and very dry air inhaled, what is the maximum loss of water vapor by the person? (b) Calculate the partial pressure of water vapor having this density, and compare it with the vapor pressure of $6.31\times10^{3}\ \text{N/m}^2$.

60. If the relative humidity is 90.0% on a muggy summer morning when the temperature is 20.0°C, what will it be later in the day when the temperature is 30.0°C, assuming the water vapor density remains constant?

61. Late on an autumn day, the relative humidity is 45.0% and the temperature is 20.0°C. What will the relative humidity be that evening when the temperature has dropped to 10.0°C, assuming constant water vapor density?

62. Atmospheric pressure atop Mt. Everest is $3.30\times10^{4}\ \text{N/m}^2$. (a) What is the partial pressure of oxygen there if it is 20.9% of the air? (b) What percent oxygen should a mountain climber breathe so that its partial pressure is the same as at sea level, where atmospheric pressure is $1.01\times10^{5}\ \text{N/m}^2$? (c) One of the most severe problems for those climbing very high mountains is the extreme drying of breathing passages. Why does this drying occur?

63. What is the dew point (the temperature at which 100% relative humidity would occur) on a day when relative humidity is 39.0% at a temperature of 20.0°C?

64. On a certain day, the temperature is 25.0°C and the relative humidity is 90.0%. How many grams of water must condense out of each cubic meter of air if the temperature falls to 15.0°C ? Such a drop in temperature can, thus, produce heavy dew or fog.

65. Integrated Concepts

The boiling point of water increases with depth because pressure increases with depth. At what depth will fresh water have a boiling point of 150°C , if the surface of the water is at sea level?

66. Integrated Concepts

(a) At what depth in fresh water is the critical pressure of water reached, given that the surface is at sea level? (b) At what temperature will this water boil? (c) Is a significantly higher temperature needed to boil water at a greater depth?

67. Integrated Concepts

To get an idea of the small effect that temperature has on Archimedes' principle, calculate the fraction of a copper block's weight that is supported by the buoyant force in 0°C water and compare this fraction with the fraction supported in 95.0°C water.

68. Integrated Concepts

If you want to cook in water at 150°C , you need a pressure cooker that can withstand the necessary pressure. (a) What pressure is required for the boiling point of water to be this high? (b) If the lid of the pressure cooker is a disk 25.0 cm in diameter, what force must it be able to withstand at this pressure?

69. Unreasonable Results

(a) How many moles per cubic meter of an ideal gas are there at a pressure of $1.00\times10^{14}\ \text{N/m}^2$ and at 0°C ? (b) What is unreasonable about this result? (c) Which premise or assumption is responsible?

70. Unreasonable Results

(a) An automobile mechanic claims that an aluminum rod fits loosely into its hole on an aluminum engine block because the engine is hot and the rod is cold. If the hole is 10.0% bigger in diameter than the 22.0°C rod, at what temperature will the rod be the same size as the hole? (b) What is unreasonable about this temperature? (c) Which premise is responsible?

71. Unreasonable Results

The temperature inside a supernova explosion is said to be $2.00\times10^{13}\ \text{K}$. (a) What would the average velocity v_{rms} of hydrogen atoms be? (b) What is unreasonable about this velocity? (c) Which premise or assumption is responsible?

72. Unreasonable Results

Suppose the relative humidity is 80% on a day when the temperature is 30.0°C . (a) What will the relative humidity be if the air cools to 25.0°C and the vapor density remains constant? (b) What is unreasonable about this result? (c) Which premise is responsible?

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13.3 The Ideal Gas Law

1. A fixed amount of ideal gas is kept in a container of fixed volume. The absolute pressure *P*, in pascals, of the gas is plotted as a function of its temperature *T*, in degrees Celsius. Which of the following are properties of a best fit curve to the data? Select *two* answers.

a. Having a positive slope
b. Passing through the origin
c. Having zero pressure at a certain negative temperature
d. Approaching zero pressure as temperature approaches infinity

2.

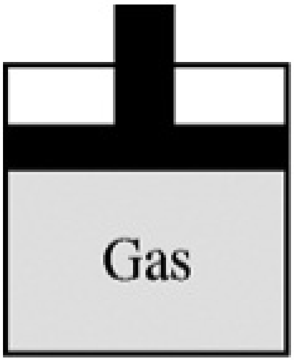

Figure 13.37 This figure shows a clear plastic container with a movable piston that contains a fixed amount of gas. A group of students is asked to determine whether the gas is ideal. The students design and conduct an experiment. They measure the three quantities recorded in the data table below.

Table 13.6

Trial	Absolute Gas Pressure (x10m^5 Pa)	Volume (m^3)	Temp. (K)		
1	1.1	0.020	270		
2	1.4	0.016	270		
3	1.9	0.012	270		
4	2.2	0.010	270		
5	2.8	0.008	270		
6	1.2	0.020	290		
7	1.5	0.016	290		
8	2.0	0.012	290		
9	2.4	0.010	290		
10	3.0	0.008	290		
11	1.3	0.020	310		
12	1.6	0.016	310		
13	2.1	0.012	310		
14	2.6	0.010	310		
15	3.2	0.008	310		

a. Select a set of data points from the table and plot those points on a graph to determine whether the gas exhibits properties of an ideal gas. Fill in blank columns in the table for any quantities you graph other than the given data. Label the axes and indicate the scale for each. Draw a best-fit line or curve through your data points.
b. Indicate whether the gas exhibits properties of an ideal gas, and explain what characteristic of your graph provides the evidence.
c. The students repeat their experiment with an identical container that contains half as much gas. They take data for the same values of volume and temperature as in the table. Would the new data result in a different conclusion about whether the gas is ideal? Justify your answer in terms of interactions between the molecules of the gas and the container walls.

13.4 Kinetic Theory: Atomic and Molecular Explanation of Pressure and Temperature

3. Two samples of ideal gas in separate containers have the same number of molecules and the same temperature, but the molecular mass of gas X is greater than that of gas Y. Which of the following correctly compares the average speed of the molecules of the gases and the average force the gases exert on their respective containers?

Table 13.7

	Average Speed of Molecules	Average Force on Container
(a)	Greater for gas X	Greater for gas X
(b)	Greater for gas X	The forces cannot be compared without knowing the volumes of the gases.
(c)	Greater for gas Y	Greater for gas Y
(d)	Greater for gas Y	The forces cannot be compared without knowing the volumes of the gases.

4. How will the average kinetic energy of a gas molecule change if its temperature is increased from 20ºC to 313ºC?

a. It will become sixteen times its original value.
b. It will become four times its original value
c. It will become double its original value
d. It will remain unchanged.

5.

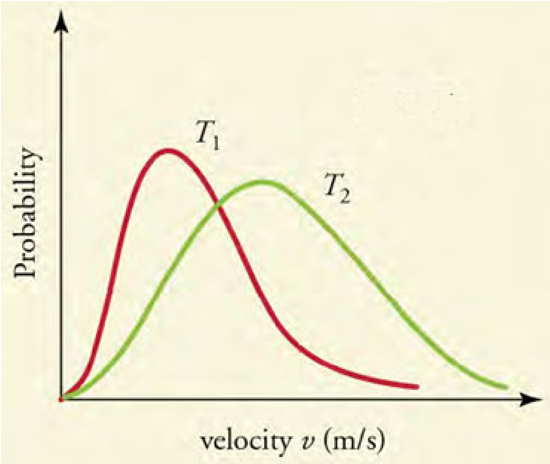

Figure 13.38 This graph shows the Maxwell-Boltzmann distribution of molecular speeds in an ideal gas for two temperatures, T_1 and T_2. Which of the following statements is false?

a. T_1 is lower than T_2
b. The *rms* speed at T_1 is higher than that at T_2.
c. The peak of each graph shows the most probable speed at the corresponding temperature.
d. None of the above.

6. Suppose you have gas in a cylinder with a movable piston which has an area of 0.40 m^2. The pressure of the gas is 150 Pa when the height of the piston is 0.02 m. Find the force exerted by the gas on the piston. How does this force change if the piston is moved to a height of 0.03 m? Assume temperature remains constant.

7. What is the average kinetic energy of a nitrogen molecule (N_2) if its *rms* speed is 560 m/s? At what temperature is this *rms* speed achieved?

8. What will be the ratio of kinetic energies and *rms* speeds of a nitrogen molecule and a helium atom at the same temperature?

(d)

Chapter 13

Problems & Exercises

1

102°F

3

20.0°C and 25.6°C

5

9890°F

7

(a) 22.2°C

(b)
$$\begin{aligned} \Delta T(^\circ\text{F}) &= T_2(^\circ\text{F}) - T_1(^\circ\text{F}) \\ &= \frac{9}{5}T_2(^\circ\text{C}) + 32.0^\circ - \left(\frac{9}{5}T_1(^\circ\text{C}) + 32.0^\circ\right) \\ &= \frac{9}{5}(T_2(^\circ\text{C}) - T_1(^\circ\text{C})) = \frac{9}{5}\Delta T(^\circ\text{C}) \end{aligned}$$

9

169.98 m

11

$5.4\times10^{-6}\text{ m}$

13

Because the area gets smaller, the price of the land DECREASES by $\sim\$17,000$.

15

$$\begin{aligned} V &= V_0 + \Delta V = V_0(1+\beta\Delta T) \\ &= (60.00\text{ L})\left[1 + \left(950\times10^{-6}/^\circ\text{C}\right)(35.0^\circ\text{C} - 15.0^\circ\text{C})\right] \\ &= 61.1\text{ L} \end{aligned}$$

17

(a) 9.35 mL

(b) 7.56 mL

19

0.832 mm

21

We know how the length changes with temperature: $\Delta L = \alpha L_0 \Delta T$. Also we know that the volume of a cube is related to its length by $V = L^3$, so the final volume is then $V = V_0 + \Delta V = (L_0 + \Delta L)^3$. Substituting for ΔL gives

$$V = (L_0 + \alpha L_0 \Delta T)^3 = L_0^3(1+\alpha\Delta T)^3.$$

Now, because $\alpha\Delta T$ is small, we can use the binomial expansion:

$$V \approx L_0^3(1 + 3\alpha\Delta \text{T}) = L_0^3 + 3\alpha L_0^3 \Delta T.$$

So writing the length terms in terms of volumes gives $V = V_0 + \Delta V \approx V_0 + 3\alpha V_0 \Delta T,$ and so

$$\Delta V = \beta V_0 \Delta T \approx 3\alpha V_0 \Delta T, \text{ or } \beta \approx 3\alpha.$$

22
1.62 atm
24
(a) 0.136 atm
(b) 0.135 atm. The difference between this value and the value from part (a) is negligible.
26
(a) $nRT = (\text{mol})(\text{J/mol}\cdot\text{K})(\text{K}) = \text{J}$
(b) $nRT = (\text{mol})(\text{cal/mol}\cdot\text{K})(\text{K}) = \text{cal}$
(c)
$$\begin{aligned} nRT &= (\text{mol})(\text{L}\cdot\text{atm/mol}\cdot\text{K})(\text{K}) \\ &= \text{L}\cdot\text{atm} = (\text{m}^3)(\text{N/m}^2) \\ &= \text{N}\cdot\text{m} = \text{J} \end{aligned}$$
28
7.86×10^{-2} mol
30
(a) $6.02\times10^{5}\ \text{km}^3$
(b) 6.02×10^{8} km
32
-73.9°C
34
(a) $9.14\times10^{6}\ \text{N/m}^2$
(b) $8.23\times10^{6}\ \text{N/m}^2$
(c) 2.16 K
(d) No. The final temperature needed is much too low to be easily achieved for a large object.
36
41 km
38
(a) 3.7×10^{-17} Pa
(b) $6.0\times10^{17}\ \text{m}^3$
(c) 8.4×10^{2} km
39
1.25×10^{3} m/s
41
(a) 1.20×10^{-19} J
(b) 1.24×10^{-17} J
43
458 K
45
1.95×10^{7} K
47
6.09×10^{5} m/s
49
7.89×10^{4} Pa
51

(a) $1.99\times10^{5}\text{ Pa}$

(b) 0.97 atm

53

$3.12\times10^{4}\text{ Pa}$

55

78.3%

57

(a) $2.12\times10^{4}\text{ Pa}$

(b) $1.06\ \%$

59

(a) $8.80\times10^{-2}\text{ g}$

(b) $6.30\times10^{3}\text{ Pa}$; the two values are nearly identical.

61

82.3%

63

4.77°C

65

38.3 m

67

$\frac{(F_\text{B}/w_\text{Cu})}{(F_\text{B}/w_\text{Cu})'} = 1.02$. The buoyant force supports nearly the exact same amount of force on the copper block in both circumstances.

69

(a) $4.41\times10^{10}\text{ mol/m}^3$

(b) It's unreasonably large.

(c) At high pressures such as these, the ideal gas law can no longer be applied. As a result, unreasonable answers come up when it is used.

71

(a) $7.03\times10^{8}\text{ m/s}$

(b) The velocity is too high—it's greater than the speed of light.

(c) The assumption that hydrogen inside a supernova behaves as an idea gas is responsible, because of the great temperature and density in the core of a star. Furthermore, when a velocity greater than the speed of light is obtained, classical physics must be replaced by relativity, a subject not yet covered.

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1

(a), (c)

3

(d)

5

(b)

7

(a) 7.29×10^{-21} J; (b) 352K or 79ºC

Chapter 14

Problems & Exercises

1

$5.02\times10^{8}\text{ J}$

3

Heat and Temperature Problems
Solved.

9/ $\alpha_{marble} = 2.5\,10^{-6}\ \frac{1}{°C}$

$\Delta L = \alpha L_0 \Delta T = 2.5 . 10^{-6} . 170 . -45 = -0.019$

$L_t = L_0 + \Delta L = 170 - 0.019 = 169.98$ m.

15/ $\Delta V = \beta V_0 \Delta T$

$\beta_{gasoline} = 950 . 10^{-6}$

$\Delta V = 950 . 10^{-6} . 60 . \cancel{10} . 20 = 1.14\ L$

$V_t = L_0 + \Delta V = 61.14\ L$

17/a/ $\Delta V = \beta V_0 \Delta T$

$\beta_{ethyl\ alcohol} = 1100 . 10^{-6} \rightarrow \Delta V = 9.35\ mL$

b/ $\Delta V_w = \beta_{water} V_0 \Delta T = 1.785\ mL$ $(\beta_{water} = 210 . 10^{-6})$

$\rightarrow \Delta V_{e.A} - \Delta V_w = 7.56\ mL$

28/ $PV = nRT \rightarrow n = \frac{PV}{RT} = \frac{1.01 . 10^{5} \times 2 . 10^{-3}}{8.31 \times (30 + 273)} = 0.078$ mols

34/ a) $\dfrac{P_i \cancel{V_i}}{T_i} = \dfrac{P_f \cancel{V_f}}{T_f} \rightarrow P_f = \dfrac{P_i}{T_i} T_f = \dfrac{1.4 \cdot 10^7}{(25+273)} (-185+2$

$\rightarrow P_f = 9.14 \cdot 10^6 \ \frac{N}{m^2}$

b/ now the volume is changing.

$\frac{1}{10} V_i$ escapes $\rightarrow V_f = \frac{9}{10} V_i = \frac{9}{10} 50 = 45L = 0.045 \ m^3$

$P_f = \dfrac{P_i V_i}{T_i V_f} \cdot T_f = \cancel{} \ 1.01 \ 10^7 \ \frac{N}{m^2}$

$V_f = V_i - \frac{1}{10} V_i = 45L$

c/ $T_f = \dfrac{P_f \cancel{V_f} T_i}{P_i \cancel{V_i}} = 2.15 K.$

d/ No.

43/ $V_{rms} = \sqrt{\dfrac{3kT}{m}} \rightarrow T = \dfrac{m V_{rms}^2}{3k}$

$m_H = \dfrac{m}{N_A} = \dfrac{2.016 \cdot 10^{-3} \ kg/mol}{6.02 \ 10^{23}} = 3.35 \cdot 10^{-27} \ kg.$

$\rightarrow T = \dfrac{3.38 \cdot 10^{-27} \cdot (2.38 \cdot 10^3)^2}{3 \cdot 1.38 \times 10^{-23}} = 459 \ K.$