SECTION 12.1 THE PROPERTIES OF GASES (pages 327–328)

This section describes the properties of gas particles and explains how the kinetic energy of gas particles relates to Kelvin temperature.

Kinetic Theory Revisited (pages 327–328)

1. What theory explains the behavior of gases with respect to conditions such as temperature and pressure? __________

2. If you notice that a sealed bag of potato chips bulges when placed near a sunny window, what can you hypothesize about the relationship between the temperature and pressure of an enclosed gas?

   An increase in temperature causes an increase in the pressure exerted by the gas.

3. List three basic assumptions of the kinetic theory about the properties of gases.
   a. Gas particles are so small in relation to the distances between them that their individual volumes can be assumed to be insignificant.
   b. No attractive or repulsive forces exist between gas particles.
   c. Gas particles are in constant random motion, traveling in independent straight paths until they collide with each other or other objects.

4. Circle the letter next to each sentence that is true concerning the compressibility of gases.
   a. The large relative distances between gas particles means that there is considerable empty space between them.
   b. The assumption that gas particles are far apart explains gas compressibility.
   c. Compressibility is a measure of how much the volume of matter decreases under pressure.
   d. Energy is released by a gas when it is compressed.

5. Look at Figure 12.1 on page 327. How does an automobile air bag protect the crash dummy from being broken as a result of impact?

   The gases used to inflate the airbag are compressible and are able to absorb a considerable amount of energy.
CHAPTER 12, The Behavior of Gases (continued)

6. List the name, the symbol, and a common unit for the four variables that are generally used to describe the characteristics of a gas.
   a. Pressure, \( P \), kilopascals
   b. Volume, \( V \), liters
   c. Temperature, \( T \), kelvins
   d. Number of particles, \( n \), moles

7. List four everyday items that rely on the behavior of gases to operate properly.
   Possible answers: automobile airbags, scuba-diving equipment, hot-air balloons, automobile tires, bicycle tires, pressure cookers, bread machines, aerosol cans, air compressors, and air brakes

SECTION 12.2 FACTORS AFFECTING GAS PRESSURE (pages 330–332)

This section explains how gas pressure is affected by the amount of gas, the volume of a container, and temperature changes.

1. How do conditions change inside a tire when you pump it up with a tire pump? Because air particles are added, the pressure increases inside the tire.

2. The diagrams below show a sealed container at three pressures. Complete the labels showing the gas pressure in each container.

3. What can happen if too much air is pumped into a tire?
   The pressure inside the tire can increase beyond the strength of its walls, causing the tire to rupture or burst.
4. Is the following sentence true or false? When a sealed container of gas is opened, gas will flow from the region of lower pressure to the region of higher pressure.  **false**

5. Look at Figure 12.7 on page 331. What happens when the spray button on an aerosol spray can is pressed?

   Pushing the button creates an opening between the atmosphere and the gas inside the can, which is at a higher pressure. Gas from inside the can rushes out of the opening, forcing the product in the can out with it.

6. In the diagram, complete the labels showing the pressure on the piston and the gas pressure inside the container.

   ![Diagram of gas pressure and volume](image)

   - Volume = 2.0 L  
   - Volume = 1.0 L  
   - Pressure = 100 kPa  
   - Pressure = 200 kPa

7. When the volume is reduced by one half, what happens to the pressure?  
   The pressure will double.

8. Is the following sentence true or false? Raising the temperature of an enclosed gas causes its pressure to decrease.  **false**

9. Circle the letter next to each sentence that correctly describes how gases behave when the temperature increases:

   a. The average kinetic energy of the gas particles increases as the particles absorb thermal energy.

   b. Faster-moving particles impact the walls of their container with more energy, exerting greater pressure.

   c. When the average kinetic energy of enclosed gas particles doubles, temperature doubles and pressure is cut in half.

10. Explain why it is dangerous to throw aerosol cans into a fire.

    Throwing an aerosol can into a fire causes the gas pressure inside the can to increase greatly, with the likelihood that the can will burst.
CHAPTER 12, The Behavior of Gases (continued)

11. How are the average kinetic energy of gas particles and their Kelvin temperature related?
   The average kinetic energy of gas particles and their Kelvin temperature are directly proportional.

12. Decide whether the following sentence is true or false, and explain your reasoning. When the temperature of a sample of steam increases from 100 °C to 200 °C, the average kinetic energy of its particles doubles.
   False. For average kinetic energy to double, the temperature must increase from 100 °C (373 K) to 473 °C (746 K).

SECTION 12.3 THE GAS LAWS (pages 333–340)

This section explains the relationship of the volume, pressure, and temperature of gases as described by Boyle's law, Charles's law, Gay-Lussac's law, and the combined gas law.

The Pressure-Volume Relationship: Boyle's Law (page 333–335)

1. Circle the letter of each sentence that is true about the relationship between the volume and the pressure of an enclosed gas held at constant temperature.
   a. When the pressure increases, the volume decreases.
   b. When the pressure decreases, the volume increases.
   c. When the pressure increases, the volume increases.
   d. When the pressure decreases, the volume decreases.

2. What is an inverse relationship for two variables?
   An inverse relationship occurs when one variable increases as the other decreases.

3. __________ law states that for a given mass of gas at a constant temperature, the volume of the gas varies inversely with pressure.

Questions 4, 5, 6, and 7 refer to the graph. This graph represents the relationship between pressure and volume for a sample of gas in a container at a constant temperature.

4. \( P_1 \times V_1 = 200 \text{kPa} \)
5. \( P_2 \times V_2 = 200 \text{kPa} \)
6. \( P_c \times V_c = 200 \text{kPa} \)
7. What do you notice about the product of pressure times volume at constant temperature? What gas law does this illustrate?

Pressure times volume is constant. This relationship illustrates Boyle’s law.

8. Look at the graph in Figure 12.11 on page 335. What two observations did Jacques Charles make about the behavior of gases from similar data?

The graphs for the gas samples are straight lines, and all the lines intersect the temperature axis at the same point, –273.15 °C.

9. The temperature at which average kinetic energy of gas particles theoretically is zero is called absolute zero.

10. What does it mean to say that two variables are directly proportional?

When one variable increases, the other increases so that the ratio of the two variables remains constant.

11. Is the following sentence true or false? Charles’s law states that when the pressure of a fixed mass of gas is held constant, the volume of the gas is directly proportional to its Kelvin temperature.  

   true

12. Charles’s law may be written \( \frac{V_1}{T_1} = \frac{V_2}{T_2} \) at constant pressure if the temperatures are measured on what scale?  

   Kelvin

13. Complete the following sentence. Gay-Lussac’s law states that the pressure of a gas is directly proportional to the Kelvin temperature if the volume is constant.

14. Gay-Lussac’s law may be written \( \frac{P_1}{T_1} = \frac{P_2}{T_2} \) if the volume is constant and if the temperatures are measured on what scale?  

   the Kelvin scale

15. Complete the missing labels in the diagram below showing the pressure change when a gas is heated at constant volume.

\[ P_1 = 100 \text{ kPa} \]
\[ T_1 = 300 \text{ K} \]
\[ V = 1 \text{ L} \]

\[ P_2 = 150 \text{ kPa} \]
\[ T_2 = 450 \text{ K} \]
\[ V = 1 \text{ L} \]
CHAPTER 12, The Behavior of Gases (continued)

The Combined Gas Law (pages 339–340)

16. Is the following sentence true or false? A single mathematical expression involving pressure, temperature, and volume can represent the gas laws of Boyle, Charles, and Gay-Lussac if one or another of these quantities is held constant.
   __________
   true

Questions 17, 18, 19, and 20 refer to the mathematical equation

\[
\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}
\]

17. What is this mathematical equation called? ________________ the combined gas law

18. Which gas law does this equation represent if temperature is held constant so that \( T_1 = T_2 \)? ________________ Boyle’s law

19. Which gas law does this equation represent if pressure is held constant so that \( P_1 = P_2 \)? ________________ Charles’s law

20. Which gas law does this equation represent if volume is held constant so that \( V_1 = V_2 \)? ________________ Gay-Lussac’s law

21. In which situations does the combined gas law enable you to do calculations when the other gas laws do not apply?
   The combined gas law allows calculations for situations where none of the variables—pressure, temperature, or volume—are constant.

SECTION 12.4 IDEAL GASES (pages 341–346)

This section explains how to use the ideal gas law to calculate the amount of gas at specified conditions of temperature, pressure and volume. This section also distinguishes between real and ideal gases.

Ideal Gas Law (pages 341–343)

1. In addition to pressure, temperature, and volume, what fourth variable must be considered when analyzing the behavior of a gas in a system?
   The fourth variable is the amount of gas in the system.

2. Look at Figure 12.16 on page 341. Assume that pressure, temperature, and volume inside the container are known. What general gas law can be used to calculate the number of moles of gas inside the container?
   the ideal gas law

3. Is the number of moles in a sample of gas directly proportional or inversely proportional to the number of particles of gas in the sample?
   directly proportional
4. At a specified temperature and pressure, is the number of moles of gas in a sample directly proportional or inversely proportional to the volume of the sample? __________ directly proportional

5. Circle the letter next to the correct description of how the combined gas law must be modified when you measure the amount of a gas in moles.
   
a. Multiply each side of the equation by the number of moles.
   
b. Add the number of moles to each side of the equation.
   
c. Divide each side of the equation by the number of moles.

6. Which variable in the equation
   
   \[
   \frac{P_1 \times V_1}{T_1 \times n_1} = \frac{P_2 \times V_2}{T_2 \times n_2}
   \]
   
is constant in Boyle’s law, Charles’s law, and Gay-Lussac’s law?
   
   The number of moles must be constant, \(n_1 = n_2\), for all three of these gas laws.

7. For what kind of gas is \(\frac{P \times V}{T \times n}\) a constant for all values of pressure, temperature, and volume under which the gas can exist? ____________________________ an ideal gas

8. When you know the volume occupied by one mole of gas at standard temperature and pressure, what constant may be evaluated? ____________________________ \(R\), the gas constant

9. Complete the table about the ideal gas law. Write what each symbol in the ideal gas law represents, the unit in which it is measured and abbreviation.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Quantity</th>
<th>Unit</th>
<th>Abbreviation for Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(P)</td>
<td>pressure</td>
<td>kilopascals</td>
<td>kPa</td>
</tr>
<tr>
<td>(V)</td>
<td>volume</td>
<td>liters</td>
<td>L</td>
</tr>
<tr>
<td>(n)</td>
<td>amount of gas</td>
<td>moles</td>
<td>mol</td>
</tr>
<tr>
<td>(R)</td>
<td>gas constant</td>
<td>liters × kilopascals</td>
<td>(\frac{L \times kPa}{K \times mol})</td>
</tr>
<tr>
<td>(T)</td>
<td>temperature</td>
<td>kelvins</td>
<td>K</td>
</tr>
</tbody>
</table>

10. Why would you use the ideal gas law when you know the gas constant instead of the combined gas law?
   
   Knowing the gas constant, \(R\), and the ideal gas law, \(P \times V = n \times R \times T\) lets you calculate the number of moles of gas at any specified values of \(P\), \(V\), and \(T\).
The Ideal Gas Law and Kinetic Theory (page 344)

11. To meet the assumptions of _________ of gases, gases must behave in an “ideal” way.

12. Circle the letter of each sentence that is true about ideal gases and the kinetic theory.
   a. An ideal gas would not follow the gas laws at all temperatures and pressures.
   b. An ideal gas would not conform to the assumptions of the kinetic theory.
   c. There is no real gas that exactly conforms to the kinetic theory and the ideal gas law.
   d. At many conditions of temperature and pressure, real gases behave very much like ideal gases.

13. Is the following sentence true or false? If a gas were truly an ideal gas, it would be impossible to liquefy or solidify it by cooling or by applying pressure.
   ________________________

14. Look at Figure 12.18 on page 344. What material is illustrated? What change of state is occurring? Is this behavior a property of an ideal gas or real gas?
   The material is dry ice, or frozen carbon dioxide. It is changing from solid to gas through sublimation. The change of state is a property of a real gas.

Departures from the Ideal Gas Law (pages 344–346)

15. A gas that follows the gas laws over a certain range of temperature and pressure is said to exhibit _________ under those conditions.

16. What ratio always equals 1 for an ideal gas?
   \[
   \frac{(P \times V)}{(n \times R \times T)}
   \]

Look at the graph in Figure 12.19 on page 344 to answer Questions 17, 18, and 19.

17. What is the magnitude of the marked intervals on the pressure axis of the graph? _______ kPa

18. Which of the gases shown deviates the most from ideal at pressures less than 20 000 kPa? _______ at °C
19. Which of the gases shown has behavior that is close to ideal ranging from near 0 kPa to almost 40 000 kPa? **CH₄ at 200 °C**

20. What are two assumptions of simple kinetic theory that are incorrect for real gases?
   a. **Gas particles are not attracted to each other.**
   b. **Gas particles have no volume.**

21. Is the following statement true or false? The presence of intermolecular forces between gas particles tends to increase volume, making the ratio \((P \times V)/(n \times R \times T)\) greater than 1. **false**

22. Is the following statement true or false? The nonzero volume of gas particles tends to increase volume, making the ratio \((P \times V)/(n \times R \times T)\) greater than 1. **true**

**SECTION 12.5 GAS MOLECULES: MIXTURES AND MOVEMENTS (pages 347–353)**

This section explains Avogadro’s hypothesis, Dalton’s law of partial pressures, and Graham’s law of effusion.

**Avogadro’s Hypothesis (pages 347–349)**

1. What is Avogadro’s hypothesis?
   
   **Avogadro’s hypothesis says that equal volumes of gases at the same temperature and pressure contain equal numbers of particles.**

2. Look at Figure 12.21 on page 347 to help you answer this question. Why is Avogadro’s hypothesis reasonable?
   
   **As long as the gas particles are not tightly packed, there is a great deal of empty space between them. A container can easily accommodate the same number of relatively large or relatively small gas particles.**

3. How many gas particles occupy a volume of 22.4 L at standard temperature and pressure? **6.02 × 10²³ particles**

**Dalton’s Law (pages 350–351)**

4. Is the following sentence true or false? Gas pressure depends only on the number of gas particles in a given volume and on their average kinetic energy—the type of particle does not matter. **true**

5. The contribution of the pressure of each gas in a mixture to the total pressure is called the **partial pressure** exerted by that gas.
CHAPTER 12, The Behavior of Gases (continued)

6. What is Dalton's law of partial pressures?
   At constant volume and temperature, the total pressure exerted by a mixture of gases is equal to the sum of the partial pressures of the component gases.

7. Container (T) in the figure below contains a mixture of the three different gases in (a), (b), and (c) at the pressures shown. Write in the pressure in container (T).

   \[
   \begin{array}{ccc}
   & 300 \text{ kPa} & 750 \text{ kPa} & 600 \text{ kPa} & 1650 \text{ kPa} \\
   (a) & & & & \\
   (b) & & & & \\
   (c) & & & & \\
   (T) & & & & \\
   \end{array}
   \]

   Graham's Law (pages 352–353)

8. The tendency of gas molecules to move from areas of higher concentration to areas of lower concentration is called ____________________.

9. What is Graham's law of effusion?
   Graham's law of effusion states that the rate of effusion of a gas is inversely proportional to the square root of the gas's molar mass.

10. Is the following sentence true or false? If two bodies with different masses have the same kinetic energy, the one with the greater mass must move faster.
    ____________________ false ____________________

Reading Skill Practice

You may sometimes forget the meaning of a key term that was introduced earlier in the textbook. When this happens, you can check its meaning in the Glossary on pages 36–46 of the Reference Section. The Glossary lists all key terms in the textbook and their meanings. You’ll find the terms listed in alphabetical order. Use the Glossary to review the meanings of all key terms introduced in Section 12.5. Write each term and its definition on a separate sheet of paper.

The wording of the definitions in the Glossary are often slightly different than how the terms are defined in the flow of the text. Students should write the Glossary definition of each term.