Name ______________________ Date ________________ Class ________________

14 THE BEHAVIOR OF GASES

SECTION 14.1 PROPERTIES OF GASES (pages 413–417)

This section uses kinetic theory to explain the properties of gases. This section also explains how gas pressure is affected by the amount of gas, its volume, and its temperature.

▶ Compressibility (pages 413–414)

1. Look at Figure 14.1 on page 413. 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 able to absorb a considerable amount of energy when they are compressed.

2. What theory explains the behavior of gases? kinetic theory

3. Circle the letter next to each sentence that is true concerning the compressibility of gases.

a. The large relative distances between particles in a gas means that there is considerable empty space between the particles.

b. The assumption that particles in a gas are relatively 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.

▶ Factors Affecting Gas Pressure (pages 414–417)

4. 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. amount of gas, *n*, moles

5. What keeps the raft in Figure 14.3 inflated?

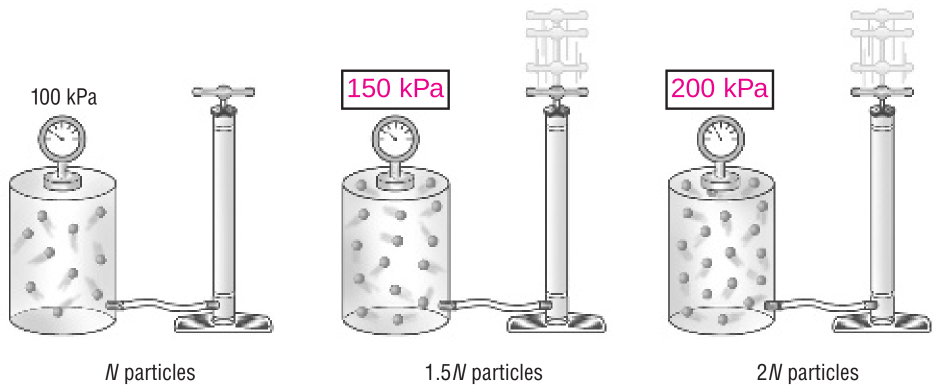
The air pressure exerted by the enclosed gas keeps the raft inflated.

CHAPTER 14, The Behavior of Gases *(continued)*

6. How do conditions change inside a rigid container when you use a pump to add gas to the container?

Because particles are added to the container, the pressure increases inside the container.

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



8. What can happen if too much gas is pumped into a sealed, rigid container?

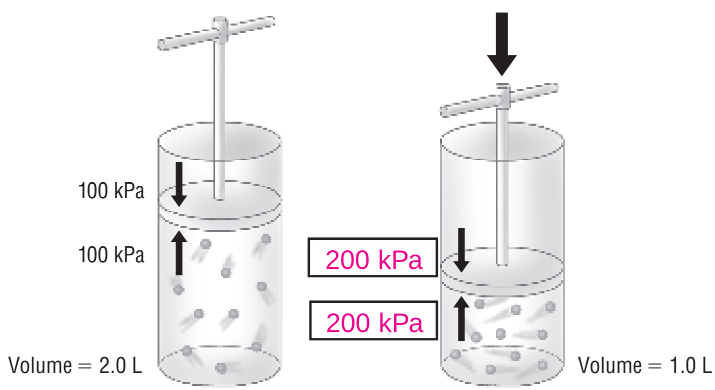
The pressure inside the container can increase beyond the strength of its walls, causing the container to rupture or burst.

9. 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______

10. Look at Figure 14.5 on page 416. What happens when the push 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.

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



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

13. Is the following sentence true or false? Raising the temperature of a contained gas causes its pressure to decrease. false

14. Circle the letter next to each sentence that correctly describes how gases behave when the temperature increases.
   a. The average kinetic energy of the particles in the gas increases as the particles absorb energy.
   b. Faster-moving particles impact the walls of their container with more force, exerting greater pressure.
   c. When the average kinetic energy of the enclosed particles doubles, temperature doubles and the pressure is cut in half.

15. 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.

16. 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 14.2 THE GAS LAWS (pages 418–425)

This section explains the relationships among 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.

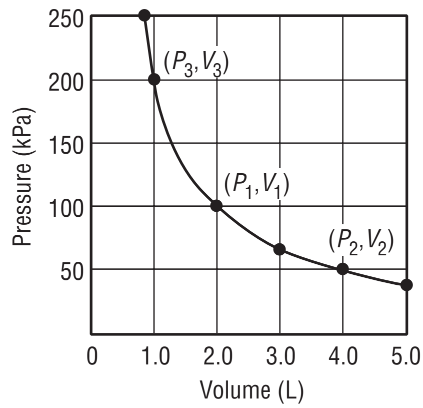
▶ Boyle's Law: Pressure and Volume (pages 418–419)

1. Circle the letter of each sentence that is true about the relationship between the volume and the pressure of a contained gas 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. Boyle's law states that for a given mass of gas at constant temperature, the volume of the gas varies inversely with pressure.

CHAPTER 14, The Behavior of Gases *(continued)*

Questions 3, 4, 5, and 6 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.



3. $P_1 \times V_1 =$ 160 kPa × 2.0 L

4. $P_2 \times V_2 =$ 50 kPa × 4.0 L

5. $P_3 \times V_3 =$ 200 kPa × 1.0 L

6. What do you notice about the product of pressure times volume at constant temperature?

Pressure times volume is constant.

▶ Charles's Law: Temperature and Volume (pages 420–421)

7. Look at the graph in Figure 14.10 on page 420. What two observations did Jacques Charles make about the behavior of gases from similar data?

The graphs for volume versus temperature of any gas is a straight line, and all the lines intersect the temperature axis at the same point, –273.15°C.

8. 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.

9. 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

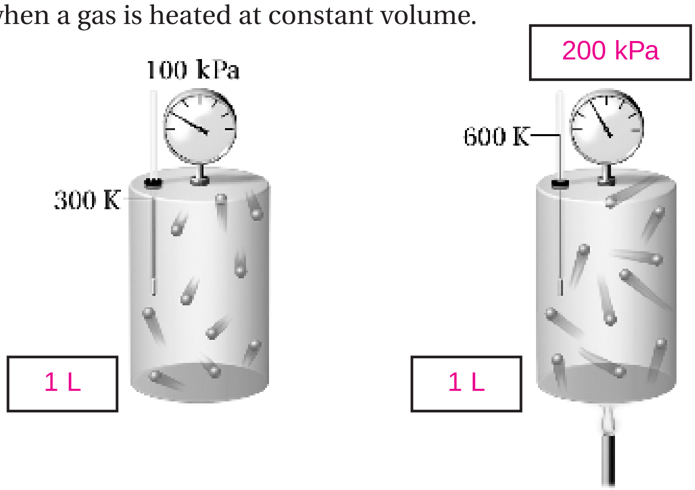
10. Charles's law may be written $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ at constant pressure if the temperatures are measured on what scale? Kelvin

▶ Gay-Lussac's Law: Pressure and Temperature (pages 422–423)

11. 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.

12. 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

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



▶ The Combined Gas Law (pages 424–425)

14. Is the following sentence true or false? The gas laws of Boyle, Charles, and Gay-Lussac can be combined into a single mathematical expression.

true

Questions 15, 16, 17, and 18 refer to the following equation

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

15. What law does this mathematical equation represent?

the combined gas law

16. Which gas law does this equation represent if temperature is held constant so that $T_1 = T_2$? Boyle's law

17. Which gas law does this equation represent if pressure is held constant so that $P_1 = P_2$? Charles's law

18. Which gas law does this equation represent if volume is held constant so that $V_1 = V_2$? Gay-Lussac's law

19. 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.

Name ____________________ Date ______________ Class ______________

SECTION 14.3 IDEAL GASES (pages 426–429)

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 real gases from ideal gases.

▶ Ideal Gas Law (pages 426–427)

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

The fourth variable is the amount of gas.

2. 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

3. 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

4. Circle the letter next to the correct description of how the combined gas law must be modified to introduce the number of 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.

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

6. What constant can you calculate when you know the volume occupied by one mole of gas at standard temperature and pressure?

R, the gas constant

Name ______________________ Date ________________ Class ________________

7. 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 the abbreviation of the unit.

Symbol	Quantity	Unit	Abbreviation for Unit
P	pressure	kilopascals	kPa
V	volume	liters	L
n	amount of gas	moles	mol
R	gas constant	$\frac{\text{liters} \times \text{kilopascals}}{\text{kelvins} \times \text{moles}}$	$\frac{\text{L}\bullet\text{kPa}}{\text{K}\bullet\text{mol}}$
T	temperature	kelvins	K

8. When would you use the ideal gas law instead of the combined gas law?

The ideal gas law lets you calculate the number of moles of gas at any specified values of P, V, and T.

▶ Ideal Gases and Real Gases (pages 428–429)

9. Circle the letter of each sentence that is true about ideal gases and real gases.

a. An ideal gas does not follow the gas laws at all temperatures and pressures.

b. An ideal gas does not conform to the assumptions of the kinetic theory.

c. There is no real gas that conforms to the kinetic theory under all conditions of temperature and pressure.

d. At many conditions of temperature and pressure, real gases behave very much like ideal gases.

10. 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.

true

11. Red gases differ most from an ideal gas at low temperatures and high pressures.

12. Look at Figure 14.14 on page 428. What substance is shown? What change of state is occurring? How do you know this substance is not an ideal gas?

The material is liquid nitrogen. It is changing from a liquid to a gas. An ideal gas could not be changed from a gas to a liquid.

Name ______________________ Date ________________ Class ________________

SECTION 14.4 GASES: MIXTURES AND MOVEMENTS (pages 432–436)

This section explains Dalton's law of partial pressures, and Graham's law of effusion.

▶ Dalton's Law (pages 432–434)

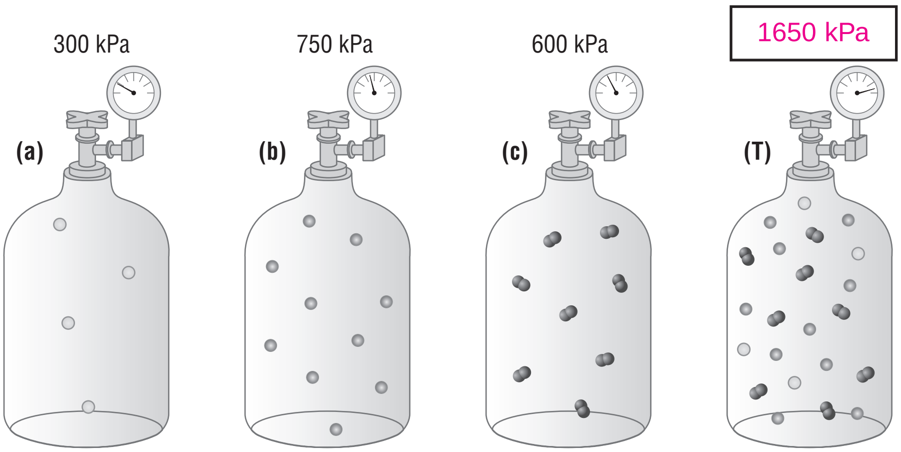
1. Is the following statement true or false? Gas pressure depends only on the number of particles in a given volume and on their average kinetic energy. The type of particle does not matter. true

2. The contribution of the pressure of each gas in a mixture to the total pressure is called the partial pressure exerted by that gas.

3. 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.

4. 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).



Name ______________________ Date ________________ Class ________________

▶ Graham's Law (pages 435–436)

5. The tendency of molecules in a gas to move from areas of higher concentration to areas of lower concentration is called diffusion.

6. 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.

7. Is the following sentence true or false? If two objects 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 vocabulary term that was introduced earlier in the textbook. When this happens, you can check its meaning in the Glossary on pages R108–R118 of the Reference Section. The Glossary lists all vocabulary 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 vocabulary terms introduced in Section 14.4. 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.

GUIDED PRACTICE PROBLEMS

GUIDED PRACTICE PROBLEM 13 (page 424)

13. A gas at 155 kPa and 25°C has an initial volume of 1.00 L. The pressure of the gas increases to 605 kPa as the temperature is raised to 125°C. What is the new volume?

Analyze

a. Temperature can be converted from Celsius to Kelvin by adding 273 .

b. What is the expression for the combined gas law?

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

c. What is the unknown in this problem? V_2

Calculate

d. Convert degrees Celsius to kelvins.

$T_1 = 25°C + \boxed{273} = \boxed{298}$ K

$T_2 = 125°C + \boxed{273} = \boxed{398}$ K

e. Rearrange the combined gas law to isolate V_2.

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

f. Substitute the known quantities into the equation and solve.

$$V_2 = \frac{1.00\text{ L} \times \boxed{155}\ \cancel{\text{kPa}} \times 398\ \cancel{\text{K}}}{605\ \cancel{\text{kPa}} \times \boxed{298}\ \cancel{\text{K}}} = \boxed{0.342\text{ L}}$$

Evaluate

g. Explain why you think your answer is reasonable.

The new volume is directly proportional to the change in temperature but inversely proportional to the change in pressure. The temperature increased by a multiple of about $\frac{4}{3}$, but the inverse of the pressure change is $\frac{1}{4}$, giving a product of $\frac{1}{3}$. Therefore, the new volume should be about $\frac{1}{3}$ the original volume.

h. Are the units in your answer correct? How do you know?

Yes, because volume is measured in liters.

Name ______________________ Date ________________ Class ________________

EXTRA PRACTICE (similar to Practice Problem 11, page 423)

11. A gas has a pressure of 7.50 kPa at 420 K. What will the pressure be at 210 K if the volume does not change?

$$P_2 = \frac{7.50\ \text{kPa} \times 210\ \text{K}}{420\ \text{K}} = 3.8\ \text{kPa}$$

GUIDED PRACTICE PROBLEM 31 (page 434)

31. Determine the total pressure of a gas mixture that contains oxygen, nitrogen, and helium if the partial pressures of the gases are as follows:

$P_{O_2} = 20.0$ kPa, $P_{N_2} = 46.7$ kPa, and $P_{He} = 26.7$ kPa.

Analyze

a. What is the expression for Dalton's law of partial pressure?

$P_{total} = P_1 + P_2 + P_3$

b. What is the unknown in this problem? P_{total}

Calculate

c. Substitute the known quantities into the equation and solve.

$P_{total} = 20.0\ \text{kPa} + 46.7\ \text{kPa} + 26.7\ \text{kPa} = 93.4\ \text{kPa}$

Evaluate

d. Why is your answer reasonable?

The total pressure can be estimated to be 20 + 50 + 25 = 95. The answer 93.4 is close to the estimate of 95.