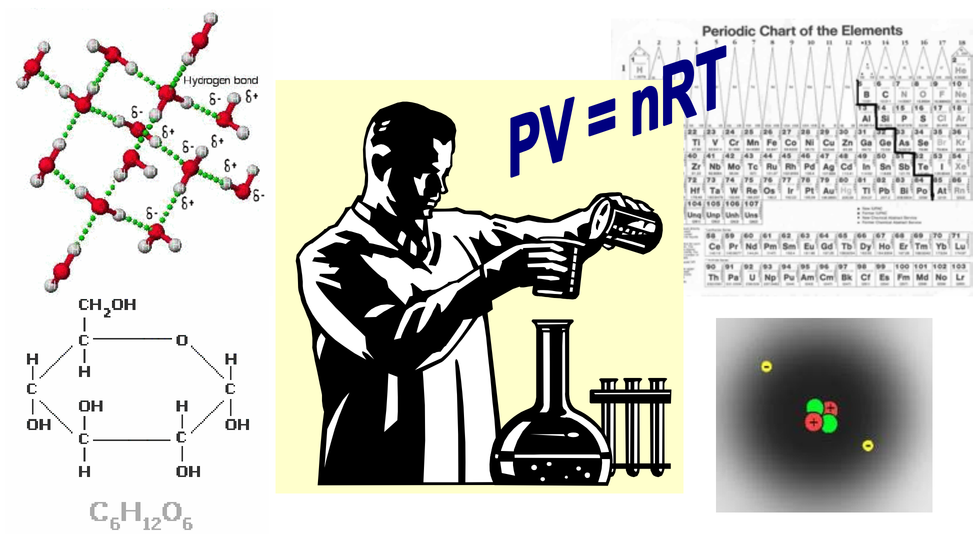
Project EASE

(Effective Alternative Secondary Education)

CHEMISTRY



MODULE 9

Gas Laws

BUREAU OF SECONDARY EDUCATION
Department of Education
DepEd Complex, Meralco Avenue
Pasig City

Module 9
Gas Laws

What this module is about

Every time we breathe through our lungs, pump air into a tire, blow up soap bubbles, or use a spray can, we are depending on gases to work in a predictable way. Have you ever wondered why gases act the way they do?

This module will introduce you to the properties of gases and the four variables we are concerned with when dealing with gases. These variables are temperature (T), pressure (P), volume (V), and the quantity of a gas in moles (n). Equations that express the relationships between these four variables are called *gas laws.* These concepts as well as the analytical skills needed to understand them will be developed as you try the activities and read the discussions presented in the four lessons of this module.

- **Lesson 1 – Boyle's Law**
- **Lesson 2 – Charles' Law**
- **Lesson 3 – Combined Gas Law and Gay-Lussac's Law**
- **Lesson 4 – Ideal Gas Law**

What you are expected to learn

After going through this module, you should be able to:

1. state the meaning associated with the characteristic properties of gases: volume, pressure, temperature and amount;
2. recognize the following symbols used to describe gases: n, P, R, T, V and STP;
3. explain the interrelationships of pressure, volume and temperature of gases;
4. solve problems involving changes in the condition of the gas using the equations for Boyle's Law, Charles' Law, Combined Gas Law, Gay-Lussac's Law and Ideal Gas Law;
5. describe the properties of an ideal gas and recognize the conditions at which gases behave ideally; and
6. describe how gas density is related to pressure, temperature and number of moles by applying the ideal gas law.

How to learn from this module

1. Familiarize yourself with the objectives of the module. Take the **Pretest**.
2. Read the **Introduction** to the lessons, beginning with Lesson 1. Think of the skills that will help you understand the lesson. If necessary, briefly review the concepts that you must know beforehand
3. Read and understand the **Discussion**. From time to time, ask yourself if you are able to acquire the concepts and skills listed in the objectives.
4. Perform the **Activities**. Record your observations and answer the guide questions.
5. The self-tests are provided to give ample practice in problem solving.
6. Do the **Self-test** to assess your understanding of the topics covered.
7. Repeat Steps 2 to 5 for the remaining lessons. Refresh your memory by reading the **Summary** of all the lessons.
8. Take the **Posttest** to see how well you understood the concepts in the module.

What to do before (Pretest)

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Who was the English scientist who made accurate observations on how pressure and volume are related?
   a. Boyle
   b. Charles
   c. Combine
   d. Gay-Lussac

2. When pressure on a gas goes down what happens to its volume?
   a. rises
   b. goes down
   c. stays the same
   d. rises, then falls

3. In the equation for Boyle's Law, P_1 stands for:
   a. new pressure
   b. original pressure
   c. difference in pressure
   d. standard pressure, 1 atm

4. As the volume of a gas goes up, what happens to the temperature of the gas?
   a. goes up
   b. goes down
   c. stays the same
   d. goes down, then up

5. The temperature and volume of a gas are directly related. This is a statement of:
   a. Boyle's Law
   b. Charles' Law
   c. Combined Gas Law
   d. the Ideal Gas Law

6. Which equation gives the correct relationship between volume and temperature of a gas?
   a. $T_1 V_1 = T_2 V_2$
   b. $T_1 V_2 = T_2 V_1$
   c. $T_2 V_1 = T_1 V_2$
   d. $T_2 V_2 = T_1 V_1$.

7. What is the standard temperature in Kelvin?
   a. 0 Kelvin
   b. 25 Kelvin
   c. 273 Kelvin
   d. 373 Kelvin

8. The greater the ________ of a gas at a given temperature, the smaller its volume.
   a. mass
   b. diffusion
   c. pressure
   d. expansion

9. In the ideal gas equation, the universal gas constant **R** has the value of ________ L · atm/ mol · K.
   a. 0.008206
   b. 0.082060
   c. 0.820600
   d. 8.206000

10. The molar volume of a gas is the volume occupied by 1 mole of a gas at:
    a. 1^oC and 1 atm
    b. 273^oC and 0 atm
    c. 1 K and 0 atm
    d. 273 K and 1 atm

11. Gases having molecules that behave as predicted by the gas laws are called:
    a. ideal gases
    b. noble gases
    c. rare gases
    d. real gases

12. A toy balloon left under the sun at noontime is likely to expand and burst. This illustrates:
    a. Boyles' Law
    b. Charles' Law
    c. Gay-Lussac's Law
    d. Avogradro's Law

13. At standard temperature and pressure, what is the volume occupied by a mole of any gas?
    a. 0.224 L
    b. 2.24 mL
    c. 22.4 L
    d. 22.4 mL

14. What happens to the density of a gas when the temperature is increased at constant pressure?
    a. decreases
    b. increases
    c. remains the same
    d. cannot be determined

15. "The density of a gas decreases with increasing temperature at constant pressure." This statement:
    a. is true
    b. is false
    c. does not apply to ideal gases
    d. can neither be scientifically proven nor disproved

16. To expand a 15 L sample of gas to 20 L, it is necessary to:
    a. increase the pressure
    b. decrease the number of moles
    c. increase the temperature
    d. decrease the temperature

17. A sample of carbon dioxide occupies 3 L at 35ºC and 1 atm. What will happen to its volume if its condition is changed to 48ºC and 1.5 atm?
    a. The volume will decrease.
    b. The volume will increase.
    c. The volume will remain the same.
    d. The volume cannot be determined.

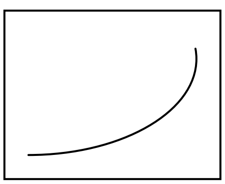
18. The J-shaped glass tube containing mercury and a sample of trapped gas was used by _________ to study the effect of pressure on volume.
    a. Boyle
    b. Charles
    c. Avogadro
    d. Gay-Lussac

19. Gases behave non-ideally under which of the following conditions?
    a. at high pressure and low temperature
    b. at low pressure and low temperature
    c. near the boiling point of water
    d. ideal gases can never exhibit non-ideal behavior

20. A graph showing the variation of volume (vertical axis) with pressure at constant temperature would look like:

Error!

a.



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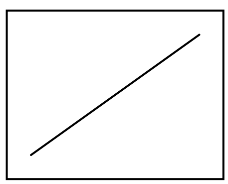

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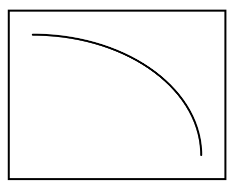

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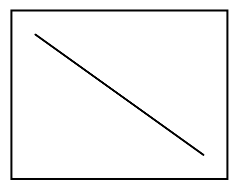


Key to answers on page 20.

Lesson 1. Boyle's Law

Introduction

Air is all around us. We breathe in the air so that our body can receive adequate supply of oxygen gas. Our lungs expand as they fill with air and take in oxygen, and relax as they release carbon dioxide. Plants in turn, use up the carbon dioxide during the process of photosynthesis to manufacture sugars. Life as we know it would not have been possible without the life-sustaining gases found in the atmosphere

Like breathing, many other human activities involve gases. When air is pumped into a bicycle or automobile tire, a mixture of gases is compressed into a small volume. Helium gas make toy balloons float. Gas used to fill rubber lifeboats and vests exerts pressure on its containers, giving them rigidity and shape.

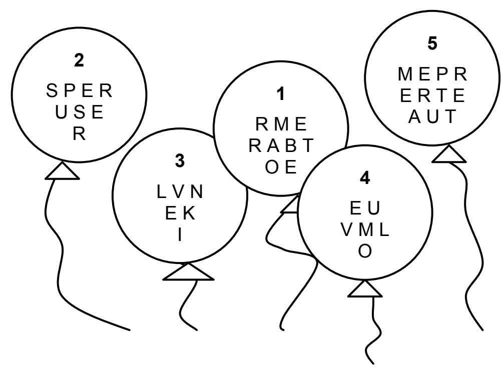
For centuries now, scientists are curious about how gases behave. Investigations on the behavior of gases mainly concern the relationship among the four important properties of gases: volume, pressure, temperature and amount in moles. This lesson introduces the relationship between volume and pressure at constant temperature, which is also known as Boyle's Law.

What you will do

Activity 1.1

Guess the words described below. Clues are given in the jumbled letters in the balloons.

1. It is an instrument consisting of a mercury-filled tube inverted in a dish of mercury. Torricelli invented it and used it to measure the pressure of a gas.
2. This is the most easily measured gas property defined as the force exerted upon a unit area of a surface.
3. It is a more fundamental temperature scale than Celsius or Fahrenheit
4. Related to mass and density, it is the total space occupied by an object.
5. This is what you measure when you want to know the degree of hotness or coldness of an object. It is defined as the average kinetic energy possessed by a sample of matter.



Key to answers on page 21.

What you will do

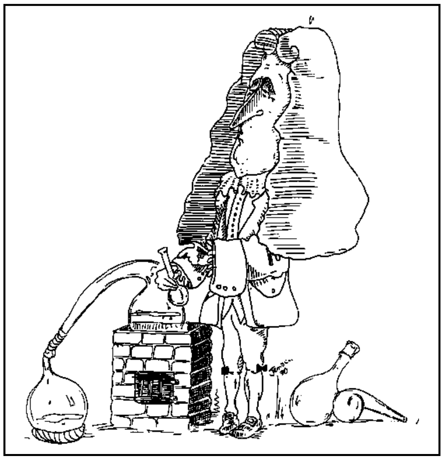
Activity 1.2

Fill in the table with commonly used units for the temperature, pressure and volume of a gas.

PHYSICAL QUANTITIES	UNITS
Temperature	
Pressure	
Volume	

Key to answers on page 21.

Discussion



One of the first scientists to study the behavior of gases was Robert Boyle. In 1661, he made a device using a J-shaped glass tube containing mercury and a sample of trapped gas similar to the figure below. He observed that the volume of the trapped gas decreased in proportion to the pressure exerted by the addition of more mercury.

Figure 1.1 Robert Boyle
http://www.woodrow.org/teachers/chemistry/institutes/1992/BOYLE.GIF

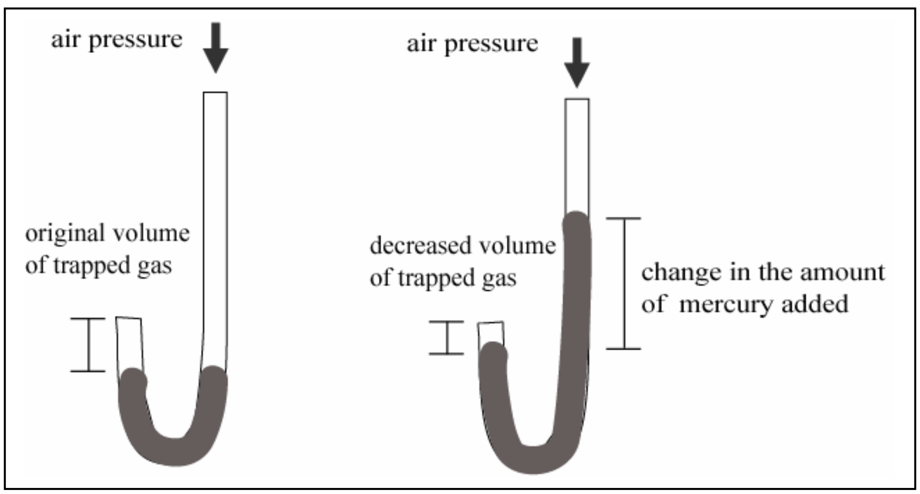


Figure 1.2 Boyle's J-shaped device

Checkpoint

What is the relationship between the different units of pressure?

***Answer**: Measurements of pressure can be easily interconverted from one unit to another. Just use the following relationships: 1 atmosphere = 760 mm of Hg = 760 torricellis = 101,325 Pascals.*

Boyle's Law states that if the temperature is held constant, the volume of a given amount of gas is inversely proportional to its pressure, $V \alpha 1/P$. Mathematically, Boyle's Law is expressed as: $P_1V_1 = P_2V_2$. The subscript of 1 refers to the original conditions while 2 refers to the new conditions. The figure on the right shows what happens to the volume of a sample of gas when pressure is increased while maintaining the temperature. Note the inverse relationship of pressure and volume.

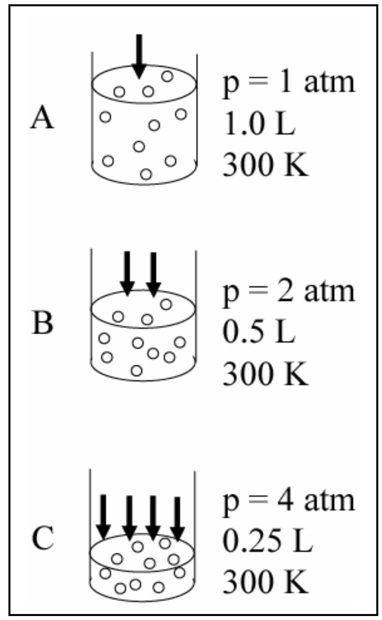


Figure 1.3 Illustration of Boyle's Law

Checkpoint

Explain in terms of Boyle's law what happens when you alternately squeeze and release a hollow rubber ball.

***Answer**: When you squeeze a hollow rubber ball, the volume decreases and the pressure within the ball increases. When the squeezing ceases, the volume increases and the pressure decreases within the ball.*

Are you ready to experience Boyle's Law in action? Try these activities on your own or together with a friend.

What you will do
Activity 1.3

In this activity, you will demonstrate Boyle's Law using simple materials. You will need several small marshmallows and a plastic syringe with a diameter large enough to fit the marshmallows. You will also need the plastic cap but not the needle of the syringe for this. Remove the plunger of the syringe and put the marshmallows inside. Return the plunger allowing only a small space for the marshmallows. Place the cap tightly (you may want to use wax to seal it). Slowly pull the plunger away and see how the marshmallows magically expand! They will return to the original size if you release the plunger. Can you explain these observations in terms of Boyle's Law?

Key to answers on page 21.

Try these Self-Test questions to check how well you understood Lesson 1.

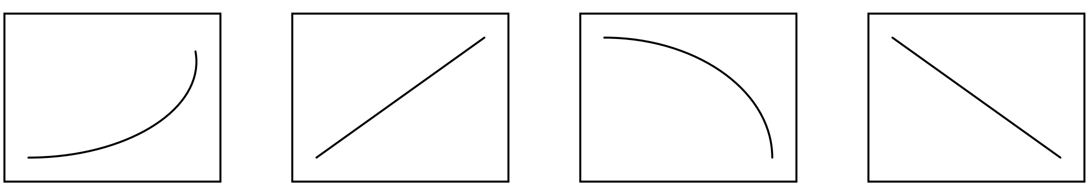
What you will do
Self-Test 1.1

Directions: Read each item carefully and supply the required information.

1. A certain model of a car has gas-filled shock absorbers to make the car run smoother and less "bumpy." Describe the gases inside the shock absorbers when the car is full of passengers compared to when the car is empty.

2. Which graph demonstrates Boyle's law? Vertical axis is V and horizontal axis is P

   a. b. c. d.



3. If the pressure on a gas is decreased by one-half, what will happen to its volume?

4. A 40 L balloon is filled with gas at 4 atm. What will be its new volume at standard pressure of 1 atm?

5. A gas at 30.0°C occupies 500 mL at a pressure of 1.00 atm. What will be its volume at a pressure of 2.50 atm?

Key to answers on page 21.

Lesson 2. Charles' Law

Introduction

In this lesson, we will investigate Charles' Law, which relates changes in the temperature of a confined gas kept at a constant pressure to the volume of the gas. You will be introduced to another equation that determines the variation of gas volume with change in temperature.

Discussion

Jacques Charles was a French chemist famous for his experiments in ballooning. Instead of hot air, he used hydrogen gas to fill balloons that could stay afloat longer and travel farther.

Figure 2.1 Jacques Charles
web.fccj.org/~ethall/gaslaw/gaslaw.htm

Charles' Law states that for a given amount of gas at constant pressure, the volume is directly proportional to the temperature in Kelvin, $V \alpha T$. Charles Law is expressed in equation form as: $T_1V_2 = T_2V_1$. The subscript of 1 refers to the original conditions while 2 refers to the new conditions. Temperatures should be expressed in Kelvin before substituting the values in the equation. The figure on the right shows what happens to the volume of a sample of gas when temperature is increased at constant pressure. Note the direct relationship of temperature and volume.

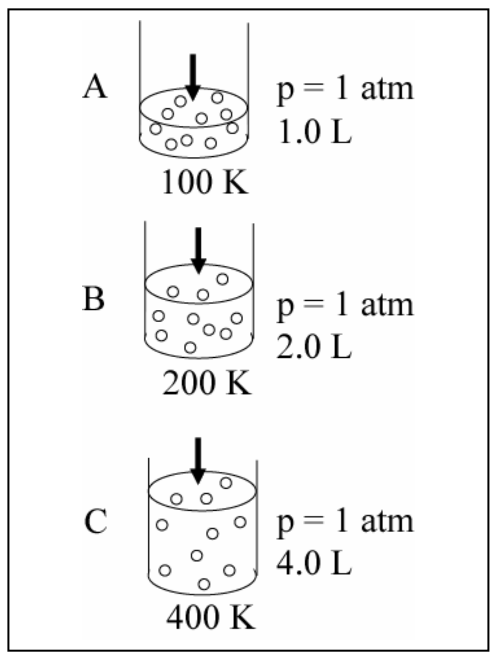


Figure 2.2
Illustration of Charles' Law

Checkpoint

What happens when a 450 mL sample of a gas kept at constant pressure is cooled from 60ºC to 20ºC?

Answer: *It decreases in volume. Identify the given data and the unknown in the problem. To apply Charles Law, convert first the temperature to Kelvin scale by adding 273. Rearrange the equation to isolate* V_2, *arriving at* $V_2 = T_2V_1 / T_1$. *If we substitute the given values, we get 396 mL as a result.*

Are you ready to experience Charles' Law in action? Try these activities on your own or together with a friend.

What you will do
Activity 2.1

For this activity, you will need 2 small basins and 3 toy balloons inflated to approximately the same size. Fill the first basin with warm water and the second with cold water. Immerse the two balloons in the separate basins. Leave the third balloon untouched.

1. Compare the balloons after 1 and 3 minutes. Which balloon expanded and which one shrunk?
2. Remove the balloons from the basin and leave at room temperature for 10 minutes. What did you observe?

Key to answers on page 21.

What you will do
Activity 2.2

For this activity, you will need to take a trip to the supermarket (or your mother's kitchen) to obtain any previously unopened jar of preserved food (examples are pickles, sandwich spread, and "Gerber" baby food) with a metal lid indicating a "freshness button."

1. Open the metal lid slowly and listen to the popping sound. What happens to the "freshness button"? What caused this sound?
2. If you put back the cover, will the button return to the "down" position? How was the button fixed in place during packing of the jar's contents?

Key to answers on page 21.

Try these Self-Test questions to check how well you understood Lesson 2.

What you will do

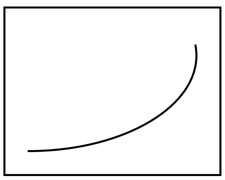
Self-Test 2.1

Directions: Read each item carefully and supply the required information.

1. For Charles' Law to apply, the gas must be kept at constant __________.

2. Which graph demonstrates Charles' law? Vertical axis is V and horizontal axis is T.

a.



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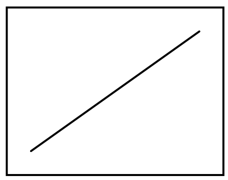

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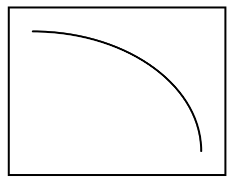

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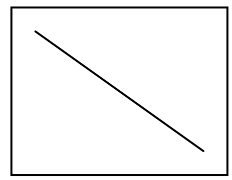

Key to answers on page 22.

What you will do

Self-Test 2.2

Directions: Read each item carefully and supply the required information.

1. A balloon was inflated to a volume of 2.5 L at 11 am when the temperature is 30°C. At 9 pm, the temperature fell to 10°C. What will be the volume of the balloon if the pressure remains constant?

2. A sample of 50.0 L of nitrogen at 20°C is compressed to 5.0 L. What must the new temperature (in Kelvin) be to maintain constant pressure?

3. Compute the decrease in temperature when 2.0 L at 280 K is compressed to 1.5 L.

Key to answers on page 22.

Lesson 3. Combined Gas Law and Gay-Lussac's Law

Introduction

The volume of a gas is greatly affected by changes in pressure and temperature, hence temperature and pressure at the time of measurement must always be specified. In this lesson, you will learn more about the Combined Gas Law, which connects the variables pressure, temperature and volume of gas. Also, you will learn about Gay-Lussac's Law, which describes how changing the temperature of a gas that is kept at constant volume affects the pressure of the gas.

Discussion

Because pressure and temperature will change from day to day and from location to location, it is common to use more than one of the gas laws to determine the resulting volume of the gas. If we combine the relationships expressing Boyle's Law, $V \alpha 1 / P$, and Charles' Law, $V \alpha T / P$, we obtain the relationship: $V \alpha T / P$. The formula for the Combined Gas Law can be expressed as: $P_1V_1T_2 = P_2V_2T_1$, where the subscript of 1 refers to the original conditions while 2 refers to the new conditions.

Checkpoint

A 350 mL sample of argon gas is collected at 295 K and 99.3 kPa. What volume would this gas occupy at STP? STP means standard temperature and pressure (1 atm and 273 K).

Answer: *317.5 mL. First, analyze the given data and the unknown. We manipulate the equation for Combined Gas Law to isolate the unknown variable V_2: $V_2 = V_1T_2P_1 / P_2T_1$. Now, substituting the values into the equation gives us the new volume, 317.5 mL.*

Gay-Lussac studied many reactions involving gases and generalized that at constant temperature and pressure, the volumes of gases can be expressed as a ratio of small whole numbers. For example, at 1 atm and 100ºC, one volume of oxygen gas combines with two volumes of hydrogen gas to give two volumes of water vapor, also at 1 atm and 100ºC. This example illustrates the Law of Combining Volumes.

Figure 3.1 Gay-Lussac
http://www.ac-nancy-metz.fr/pres-etab/lapicque/Opinfo00/Genin/GayLussac.jpg

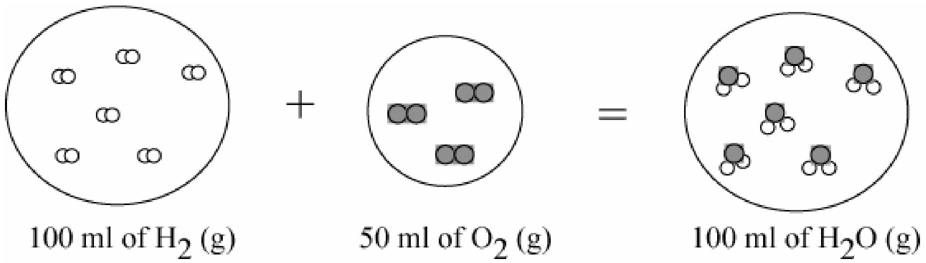

Figure 3.2 Gay-Lussac's Law

Gay-Lussac's Law states that if the temperature is held constant, the volume of a given amount of gas is inversely proportional to its pressure. This relationship is expressed by the equation: $P_1T_1 = P_2T_2$.

What you will do

Activity 3.1

Blow up a small balloon with as much air as possible without bursting it. Tie a secure knot to ensure that no air escapes. Leave the balloon at room temperature for an hour or so. Then place the balloon in hot water and check the tension of the balloon's skin for several minutes. Make a scale from 1-5 (1 = very low tension and 5 = very high tension) to rate the tension of the balloon's skin. Can you explain your results?

Key to answers on page 22.

Try these Self-Test questions to check how well you understood Lesson 3.

What you will do

Self-Test 3.1

Directions: Read the item carefully and supply the required information.

A 5000 mL container is filled with helium gas to a pressure of 3.0 atm at 250ºC. Approximately how many toy balloons at STP can be filled by helium from this container, assuming each balloon can contain 1 L? Recall that STP means standard temperature and pressure (1 atm and 273 K).

Key to answers on page 22.

What you will do
Self-Test 3.2

Directions: Read each item carefully and supply the required information.

1. A bicycle tire was inflated to a pressure of 3.74 atm during early morning when the temperature was 15ºC. At noontime, the temperature rose to 35ºC. What was the resulting pressure in the tire (assuming that its volume did not change)?

2. Helium-filled balloons can be used to carry weather instruments high into the atmosphere. Before launching, a certain balloon has a volume of 1.0×10^6 L at 22.5 C and 754 mm Hg. What will happen to the balloon when it reaches the height of 30 km, where the pressure is 76.0 mm Hg and the temperature is 240 K?

Key to answers on page 22.

Lesson 4. Ideal Gas Law

Introduction

Certain hair spray products are packaged in aerosol cans. Serious accidents could occur if you throw the empty cans into the fire because the pressurized gas could explode. These cans usually have a printed warning such as “Do not puncture or incinerate” but users seldom read what is on the label.

A gas that behaves exactly as described by the gas laws is called an **ideal gas**. Many gases, especially at high pressure or low temperatures do not behave quite ideally, hence they are called **real gases**. This lesson applies the gas laws covered in Lessons 1 and 2 to derive the Ideal Gas Law and analyze how it governs ideal gas behavior.

Discussion

If we combine the relationships expressing <u>Boyle’s Law</u>,

$$V \alpha 1 / P,$$

<u>Charles’ Law</u>,

$$V \alpha T$$

and the proportionality

$$V \alpha\ n$$

where (n stands for the number of moles of gas), we obtain the relationship:

$$V \alpha\ nT / P.$$

By introducing a constant, this relationship can be expressed as the equation V = RnT/P, and further simplified to

$$PV = nRT$$

where **R** is called the universal gas constant.

> **Checkpoint**
>
> If you plug in the standard units of pressure, volume, amount and temperature of gas in the equation, what is the resulting unit of **R**?
>
> ***Answer***: *The unit of **R** is liter atmosphere/mole Kelvin. The value of **R** if atmosphere is used as the unit of pressure is 0.08206 L · atm/mol K. If kilopascal is used as the unit of pressure, **R** becomes 8.314 L kPa/mol K.*

Notice that if you know the values of any three characteristic properties of gas, you can easily calculate the fourth property. Remember that temperatures should be expressed in Kelvin before substituting the values in the equation.

> **Checkpoint**
>
> What is the volume of 1 mole of an ideal gas at STP?
>
> ***Answer***: *22.4 L. Substitute the values for STP (1 atm and 273 K) and see for yourself. 22.4 L is the volume of a mole of any gas at standard conditions. This is called the molar volume of an ideal gas.*

A chemist named Amadeo Avogadro studied the properties of many different gases. In 1811, he concluded that equal volumes of all gases, when measured under the same conditions of temperature and pressure, always contain the same number of molecules. This relationship, $V \alpha\ n$, is known as the Avogadro's Law, which you encountered at the beginning of the lesson. It is very useful because it tells us that one mole of an ideal gas (it doesn't matter which type of gas!) at STP will always occupy 22.4 L.

Checkpoint

Is the following statement true or false? "The density of a gas varies with temperature and pressure."

Answer*: True. Notice that the ideal gas equation can be rearranged as: n/V = RT/P. n is number of moles, obtained by dividing mass in grams by the molar mass, M. Substituting m/M. gives us the equation m/V = PM/ RT. Obviously, m/V is mass divided by volume, also known as* ***density****. Thus, density is directly proportional to P and inversely proportional to T.*

As implied in the equation above, the density of the gas is also proportional to its molar mass. Thus, He gas (molar mass = 4 g/mol) is less dense than O_2 gas (molar mass = 32 g/mol).

Here are some useful tips: When three of the variables **P**, **V**, **n**, and **T** are known and you are looking for the value of the fourth variable, use the ideal gas equation. When you have only one gas sample in one set of conditions and you are asked to determine the change in one variable under a new set of conditions, just use the Combined Gas Law.

What you will do

Activity 4.1

Complete the following table:

Data on a sample of oxygen gas.

n	?	T	V	?
0.00625 mol	1.0 atm	293 K	**?**	0.08206

Key to answers on page 22.

Try these Self-test questions to check how well you understood Lesson 4.

What you will do

Self-Test 4.1

Directions: The following list contains the key terms discussed from Lesson 1 to Lesson 4. Briefly explain the concepts associated with each term.

1. pressure, P ______________________________
2. volume, V ______________________________
3. temperature, T ______________________________
4. Boyle's Law ______________________________
5. Charles Law ______________________________
6. Combined Gas Law ______________________________
7. Gay-Lussac's Law ______________________________
8. standard temperature and pressure, STP ____________________
9. gas density ______________________________
10. ideal gas constant, R ______________________________

Key to answers on page 22.

Let's Summarize

1. Gases exhibit definite behaviors that may be identified and analyzed.

2. Standard Temperature and Pressure, STP, refers to accepted experimental conditions for the study of gases, 1 atm and 273 K.

3. Boyle's Law demonstrates that at constant temperature, gas volume varies inversely with pressure.

$$P_1V_1 = P_2V_2$$

4. Charles' Law predicts that at constant pressure, gas volume varies directly with temperature changes.

$$V_1T_2 = V_2T_1$$

5. Temperature, pressure and volume are all interrelated and several changes may occur simultaneously and can be determined using the Combined Gas Law.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

6. Gay-Lussac's Law shows that at constant volume, the pressure of a gas is proportional to its temperature.

7. The Ideal Gas Law is an equation that relates the variables pressure, volume and temperature of a gas to the number of moles of gas present.

$$PV = nRT$$

Posttest

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Who was the English scientist who made accurate observations on how pressure and volume were related?
   a. Josef Boyle
   b. Gay Lussac
   c. Robert Boyle
   d. Jacques Charles

2. When pressure on a gas is reduced to half, what happens to its volume?
   a. doubles
   b. reduced to half
   c. stays the same
   d. rises, then falls

3. In the equation for Boyle's Law, P_2 stands for:
   a. new pressure
   b. original pressure
   c. difference in pressure
   d. standard pressure, 1 atm

4. The volume of a gas increases to 150%. What happens to its temperature?
   c. rises
   d. falls
   c. stays the same
   d. rises then falls

5. The equation $P_1V_1 = P_2V_2$ is known as:
   a. the Combined Gas Law
   b. Charles' Law
   c. Boyle's Law
   d. the Ideal Gas Law

6. The mathematical statement of Charles' Law is
   a. $T_1V_1 = T_2V_2$
   b. $T_1V_2 = T_2V_1$
   c. $T_2V_1 = T_1V_2$
   d. $T_2V_2 = T_1V_1$

7. Which value represents the standard temperature?
   a. 0 K
   b. 273ºC
   c. 273 K
   d. 373 K

8. "In the ideal gas equation, the constant R always has the numerical value of 0.08206, so it is called the Universal Gas Constant." This statement:
   a. is true
   b. is false

   c. is true only for ideal gases
   d. can neither be scientifically proven nor disproved

9. The molar volume of a gas is the volume occupied at STP by
   a. 0.08206 mol of the gas
   b. 1 molecule of the gas
   c. 22.4 g of the gas
   d. 6.022×10^{23} particles of the gas

10. Which of the following statements describes an ideal gas?
    a. behaves as predicted by the ideal gas law
    b. has molecules that do not attract one another
    c. has molecules that are considered volumeless
    d. all of the above

11. At STP, samples of different gases having the same volume of 22.4 L will have different:
    a. masses
    b. moles
    c. pressure
    d. temperature

12. Which statement best describes the relationship of the density of a gas to the temperature and pressure?
    a. Density increases with increasing pressure at a given temperature.
    b. Density decreases with increasing pressure at a given temperature.
    c. Density increases with increasing temperature at a given pressure.
    d. Density decreases with increasing temperature at a given pressure.

13. At a given temperature, a gas can be compressed to a smaller volume by:
    a. increasing the pressure
    b. decreasing the pressure
    c. increasing the kinetic energy
    d. increasing the number of moles

14. It's 12 noon and you just bought a dozen balloons for your little sister's birthday. Upon arriving at your house after traveling for more than an hour, you found that some of the balloons had burst (but the atmospheric pressure did not change at all). You accept this as a consequence of:
    a. Boyles' Law
    b. Charles' Law
    c. Gay-Lussac's Law
    d. your own carelessness

15. Which of the following statements about the density of a gas is correct?
    a. It is not affected by temperature.
    b. It is independent of pressure and temperature.
    c. It decreases with increasing temperature at constant pressure.
    d. It doubles when the volume of the container is doubled without a change in pressure or temperature.

16. What will happen if we heat a 15 L sample of gas from 250 K to 290 K under constant pressure condition?
    a. The volume of gas increases.
    b. The volume of gas decreases.
    c. The number of moles of gas increases.
    d. The number of moles of gas decreases.

17. A sample of carbon dioxide occupies 3 L at 35 ºC and 1 atm. What is the new volume of the gas at 48 ºC and 1.5 atm?

a. 1.0 L
b. 2.1 L
c. 3.0 L
d. 4.2 L

18. The J-shaped glass tube containing mercury and a sample of trapped gas was used by _________ to measure the reduction in volume as more mercury is added.

a. Boyle
b. Charles
c. Avogadro
d. Gay-Lussac

19. Real gases approach ideal behavior under which of the following conditions?

a. at high pressure and high temperature
b. at low pressure and high temperature
c. near the boiling point of water
d. real gases can never exhibit ideal behavior

20. A graph showing the variation of volume (vertical axis) with temperature (horizontal axis) at constant pressure would look like:

a. b. c. d.

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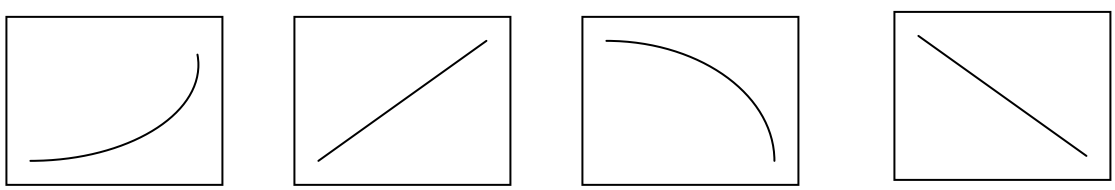

Key to answers on page 23.

Key to Answers

Pretest

1. a	6. b	11. a	16. c
2. a	7. c	12. b	17. a
3. b	8. c	13. c	18. a
4. a	9. a	14. a	19. a
5. b	10. d	15. a	20. d

Lesson 1

Activity 1.1

1. barometer
2. pressure
3. Kelvin
4. volume
5. temperature

Activity 1.2

Table of commonly used units for the temperature, pressure and volume of a gas.

PHYSICAL QUANTITIES	UNITS
Temperature	°C, °F, K
Pressure	torr. Pa, kPa, mm Hg, cm Hg
Volume	cm^3, m^3

Activity 1.3

Marshmallows are mostly air and sugar. When the plunger is pulled away, the pressure is reduced, allowing the air inside the marshmallows to increase in volume.

Self-Test 1.1

1. The gas will become more compressed when the weight of the passengers increase the pressure applied on the shock absorbers.
2. d
3. double
4. 120 L
5. 200 ml

Lesson 2

Activity 2.1

1. The gases inside the balloons increased in volume causing the change in size in proportion to time immersed in water. The balloon dipped in hot water expanded while the one in cold water shrunk.
2. The balloons reached normal size as they returned to room temperature.

Activity 2.2

1. A small volume of gas inside the jar expanded and escaped when the lid was opened.

2. The button stays up. During packing, the contents and the jar were hot. When lid is closed tightly and the jar is left to cool, a decrease in temperature causes the trapped gas to contract, pulling the button to the "down" position.

Self-Test 2.1

1. pressure
2. b

Self-Test 2.2

1. 2.33 L
2. 29.3 K
3. temperature decreases by 70 K

Lesson 3

Activity 3.1

The tension on the surface of the balloon increased the longer it was exposed to hot water. Heating caused the rise in the pressure of the gas inside the balloon, as predicted by Gay-Lussac's Law. Volume was kept constant since the completely filled balloon could not expand anymore.

Self-Test 3.1

approximately 8 balloons (since the volume at STP is 7.83 L)

Self-Test 3.2

1. 4.0 atm
2. balloon will expand to 8.05 x 10^6 L

Lesson 4

Activity 4.1

Data on a sample of oxygen gas.

n	P	T	V	R
0.00625 mol	1.0 atm	293 K	150 ml	0.08206

Self-Test 4.1

1. force exerted on the object divided by the area of the surface;
2. total space occupied by matter; for gases, volume is expressed in mL or L.

3. physical property measuring the hotness or coldness of an object.
4. states that the volume of a fixed quantity of gas at a constant temperature is inversely proportional to the pressure.
5. states that the volume of gas at a constant pressure is directly proportional to its temperature.
6. states the pressure a gas maintained at constant volume is directly proportional to its temperature.
7. equation combining the relationships between pressure, volume and temperature.
8. accepted experimental condition for the study of gases, 1 atm and 273 K
9. ratio of the mass of the gas to its volume
10. proportionality constant in the ideal gas equation, equal to 0.08206 L atm/mol K

Posttest

1. c	6. b	11. a	16. a
2. a	7. c	12. a	17. b
3. a	8. b	13. a	18. b
4. a	9. d	14. b	19. b
5. c	10.d	15. c	20. b

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