Lesson 3 | The Behavior of Gases

<table>
<thead>
<tr>
<th>Student Labs and Activities</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Launch Lab</td>
<td>46</td>
</tr>
<tr>
<td>Content Vocabulary</td>
<td>47</td>
</tr>
<tr>
<td>Lesson Outline</td>
<td>48</td>
</tr>
<tr>
<td>MiniLab</td>
<td>50</td>
</tr>
<tr>
<td>Content Practice A</td>
<td>51</td>
</tr>
<tr>
<td>Content Practice B</td>
<td>52</td>
</tr>
<tr>
<td>Math Skills</td>
<td>53</td>
</tr>
<tr>
<td>School to Home</td>
<td>54</td>
</tr>
<tr>
<td>Key Concept Builders</td>
<td>55</td>
</tr>
<tr>
<td>Enrichment</td>
<td>59</td>
</tr>
<tr>
<td>Challenge</td>
<td>60</td>
</tr>
<tr>
<td>Lab A</td>
<td>63</td>
</tr>
<tr>
<td>Lab B</td>
<td>66</td>
</tr>
<tr>
<td>Lab C</td>
<td>69</td>
</tr>
<tr>
<td>Chapter Key Concepts Builder</td>
<td>70</td>
</tr>
</tbody>
</table>
Are volume and pressure of a gas related?

Pressure affects gases differently than it affects solids and liquids. How do pressure changes affect the volume of a gas?

**Procedure**

1. Read and complete a lab safety form.
2. Stretch and blow up a small balloon several times.
3. Finally, blow up the balloon to a diameter of about 5 cm. Twist the neck, and stretch the mouth of the balloon over the opening of a plastic bottle. Tape the neck of the balloon to the bottle.
4. Squeeze and release the bottle several times while observing the balloon. Record your observations in the Data and Observations section below.

**Data and Observations**

**Think About This**

1. Why doesn't the balloon deflate when you attach it to the bottle?

2. What caused the balloon to inflate when you squeezed the bottle?

3. **Key Concept** Using this lab as a reference, do you think pressure and volume of a gas are related? Explain.
The Behavior of Gases

Directions: Answer each question on the lines provided. You must include the terms below in your answer.

Boyle’s law       Charles’s law       kinetic molecular theory       pressure

1. Temperature, pressure, and volume affect the behavior of gases. Which variable is held constant in the relationship described by Boyle’s law?

2. Boyle’s law describes a relationship relating to increases and decreases relative to two of these variables. What are these two variables?

3. Temperature, pressure, and volume affect the behavior of gases. Which variable is held constant in Charles’s law?

4. Charles’s law describes a relationship relating to increases and decreases relative to two of these variables. What are these two variables?

5. Pressure is defined as “the amount of force applied per unit of area.” For a sample of gas in a container, how would pressure be affected by an increase in the volume of the container?

6. What are four main ideas that are represented in the kinetic molecular theory?
The Behavior of Gases

A. Understanding Gas Behavior

1. Temperature, pressure, and __________________________ changes affect gases more than they do solids and __________________________.

2. The __________________________ theory is an explanation of how particles behave in matter.
   a. One idea of this theory is that all matter is made of __________________________ particles.
   b. These particles are in constant, __________________________ motion.
   c. The particles __________________________ with other objects around them.
   d. Energy is not __________________________ when particles collide.

B. What is pressure?

1. __________________________ is the result of particles’ colliding with their container.

2. Pressure is the amount of __________________________ exerted per unit of area.

C. Pressure and Volume

1. When the volume of a sample of gas decreases, __________________________ increases.

2. Pressure increases because the gas is __________________________ and there are more collisions with the __________________________.

3. When the volume of a sample of gas __________________________, pressure decreases.

4. Fewer __________________________ occur when the volume of a gas increases.

D. Boyle’s Law

1. The scientist Robert Boyle described the relationship between the __________________________ and the __________________________ of a gas.

2. Boyle’s law states that when either volume or __________________________ increases, the other property decreases, when __________________________ is constant.

E. Temperature and Volume

1. Gas behavior is also affected by __________________________ changes.
Lesson Outline continued

2. When temperature increases, the ________________ of gas particles also increases.
   a. As kinetic energy increases, particles move ________________, and volume ________________.
   b. In the same way, as kinetic energy decreases, particles move ________________, and volume ________________.

F. Charles’s Law
   1. Jacque Charles related ________________ and ________________ of a gas, assuming ________________ stays constant.
   2. ________________ states that the volume of a gas increases with increasing temperature if the pressure is constant.
   3. As an example of Charles’s law, when a balloon cools, its volume ________________ and the balloon appears partially deflated.
   4. A graph of Charles’s law might include −273°C, which is called ________________.
      a. Absolute zero is theoretically the ________________ possible temperature of matter.
      b. At absolute zero, scientists theorize that particles do not ________________.
MiniLab

LESSON 3: 20 minutes

How does temperature affect the volume?

You can observe Charles's law in action using a few lab supplies.

**Procedure**

1. Read and complete a lab safety form.
2. Stretch and blow up a **small balloon** several times.
3. Finally, blow up the balloon to a diameter of about 5 cm. Twist the neck and stretch the mouth of the balloon over the opening of an **ovenproof** flask.
4. Place the flask on a cold **hot plate**. Turn on the hot plate to low, and gradually heat the flask. Record your observations in the Data and Observations section below.
5. Use **tongs** to remove the flask from the hot plate. Allow the flask to cool for 5 min. Record your observations.
6. Place the flask in a **bowl of ice water**. Record your observations.

**Data and Observations**

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**Analyze and Conclude**

**Key Concept** What is the effect of temperature changes on the volume of a gas?
The Behavior of Gases

Directions: On each line, write the term from the word bank that correctly completes each sentence. Some terms may be used more than once or not at all.

absolute zero  collide  curved line  decrease
energy         increase  molecular  pressure
straight line  temperature  volume

1. The kinetic __________________ theory explains how particles in matter behave.

2. Particles in matter __________________ with the walls of their container, creating pressure.

3. __________________ is the amount of force per unit area.

4. Changes in temperature, pressure, and __________________ affect gases more than solids or liquids.

5. As gas is compressed, the spaces between the particles __________________.

6. The pressure-volume graph for a gas at a constant temperature is a(n) __________________.

7. The temperature-volume graph for a gas at a constant pressure is a(n) __________________.

8. The lowest possible temperature at which particles no longer move is called __________________.
The Behavior of Gases

Directions: Answer each question or respond to each statement on the lines provided.

1. **Describe** two ideas in the kinetic molecular theory.

2. For a gas at a constant temperature in a fixed container, how are pressure and volume related? What is this relationship called?

3. For a gas at constant pressure, how are temperature and volume related? What is this relationship called?

4. **Describe** a graph that can be used to illustrate Boyle’s law.

5. **Describe** a graph that can be used to illustrate Charles’s law.

6. How are Boyle’s law and Charles’s law alike? How are they different?
Solve Equations

Boyle's law describes the relationship between the pressure and volume of a gas at a constant temperature. The pressure of a gas increases if the volume decreases, and the pressure decreases if the volume increases. This law can be represented by the equation

\[ V_2 = \frac{P_1 V_1}{P_2}, \]

where \( V_1 \) = initial volume, \( V_2 \) = final volume, \( P_1 \) = initial pressure, and \( P_2 \) = final pressure. Volume is often measured in milliliters (mL) or liters (L), and pressure is often measured in kilopascals (kPa).

A gas has a volume of 1 L at a pressure of 750 kPa. If the pressure decreases to 250 kPa, what is the final volume of the gas?

Step 1 Identify the variables given in the problem.

\[ V_1 = 1 \text{ L} \]

\[ P_1 = 750 \text{ kPa} \]

\[ P_2 = 250 \text{ kPa} \]

Step 2 Insert the known values into the equation. Cancel units, multiply, and then divide to solve.

\[ V_2 = \frac{(750 \text{ kPa})(1 \text{ L})}{(250 \text{ kPa})} \]

\[ V_2 = 3 \text{ L} \]

Practice

1. A gas has a volume of 40 mL at a pressure of 800 kPa. If the pressure decreases to 200 kPa, what is the final volume of the gas?

2. What is the final volume of a gas with an initial volume of 6 L if the pressure increases from 150 kPa to 450 kPa?

3. At 480 kPa a sample of gas has a volume of 30 mL. What is the volume of the gas at 180 kPa?

4. A gas has a volume of 1.5 L at 375 kPa. If the pressure increases to 750 kPa, what is the final volume of the gas?
The Behavior of Gases

Directions: Use your textbook to answer each question and respond to each statement.

1. Fill in the table below to compare Boyle's law and Charles's law.

<table>
<thead>
<tr>
<th>Comparing Boyle's Law and Charles's Law</th>
<th>Variables That Change</th>
<th>Variable That Remains Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boyle's Law</td>
<td>a.</td>
<td>b.</td>
</tr>
<tr>
<td>Charles's Law</td>
<td>c.</td>
<td>d.</td>
</tr>
</tbody>
</table>

2. Boyle's law and Charles's law both describe the behavior of which state of matter?

3. Describe an example of Boyle's law in action. Use the words *temperature*, *volume*, and *pressure* in your description.

4. Describe an example of Charles's law in action. Use the words *temperature*, *volume*, and *pressure* in your description.
The Behavior of Gases

Key Concept  How does the kinetic molecular theory describe the behavior of a gas?

Directions: Respond to each statement in the space provided.

Explain the theory of kinetic molecular theory.
1. 

List the four basic ideas of the kinetic molecular theory.
2. 

3. 

4. 

5. 
The Behavior of Gases

Key Concept  How are temperature, pressure, and volume related in Boyle’s law?

Directions: Circle the term in parentheses that correctly completes each sentence. Use the diagram to respond to the statements.

Boyle’s Law
Relationship Between Pressure and Volume
of Gas at a Constant Pressure

1. Pressure of a gas (decreases, increases) if the volume decreases when temperature is constant.
2. Pressure of a gas (decreases, increases) if the volume increases when temperature is constant.
3. The (left, right) cylinder shows that less volume results in increased pressure.
4. From left to right, the pressure on the cylinders (increases, decreases) because the weights are greater.
5. As the volume increases, there are (more, fewer) collisions between the particles.
6. A greater number of collisions results in (greater, less) pressure.
7. Boyle’s law only applies when the (temperature, pressure) is constant.
The Behavior of Gases

Key Concept  How is Boyle’s law different from Charles’s law?

Directions: Circle the term in parentheses that correctly completes each sentence. Use the diagram to respond to the statements.

1. (Boyle’s law, Charles’s law) is about the relationship between temperature and volume.
2. (Boyle’s law, Charles’s law) is about the relationship between pressure and volume.
3. From right to left, the pressure on the cylinders (increases, stays the same).
4. The (left, right) cylinder shows that lower temperature results in less volume.
5. The (mass, volume) of the gas increases as the temperature increases.
6. Charles’s law only applies when the (temperature, pressure) is constant.
The Behavior of Gases

Key Concept  How is Boyle’s law different from Charles’s law?

Directions: Complete the Venn diagram by writing each statement’s number in the correct part of the ovals.

1. The pressure must be constant for this law to apply.
2. The particles in a gas collide with other particles and the walls of their container.
3. As the pressure increases, the volume decreases.
4. The graph illustrating this relationship is a straight line.
5. The volume of a gas decreases when the particles get closer together.
6. The temperature must be constant for this law to apply.
7. As the temperature increases, the volume also increases.
8. The graph illustrating this relationship is a curved line.
9. The bubbles exhaled by a scuba diver increase in size as the diver approaches the surface.
10. The plunger on a meat thermometer pops out when the meat is done.
11. Your ears may pop due to increased pressure as an airplane ascends.
12. When particles collide, no energy is lost.
13. A balloon blown up inside and then taken outside on a winter day shrinks slightly.
Temperature and Pressure

You’ve learned about the effect of pressure and temperature on the volume of a gas. What happens if you heat a gas in a container that has a fixed volume?

If you leave an unopened can of soda in a hot car, the liquid absorbs energy and gets hot. The gas that makes the soda fizzy also gets hot. Charles’s law states that, as the temperature of a gas increases, its volume increases. But the volume can’t increase, because the can is sealed. If the pressure gets too great, the material in the can might fail and the can could explode.

**Gay-Lussac’s Law**

Boyle’s law describes the relationship between gas pressure and volume. Charles’s law describes the relationship between temperature and volume. In 1802, a French chemist named Joseph Gay-Lussac discovered the relationship between the temperature and pressure of a gas. He stated that the pressure of a gas is directly proportional to the Kelvin temperature as long as the volume remains constant. In other words, as the temperature goes up, the pressure goes up.

**Does this make sense?**

You can use the kinetic molecular theory to predict the effect of temperature on pressure. You know that, as you heat a gas, the particles gain kinetic energy. Their motion increases. So, if the gas is in an enclosed container, the particles will strike the sides of the container more often and with greater force. Because pressure is the force per unit of area, the pressure must increase as the temperature increases.

**Why does it matter?**

When you ride your bike on a hot day, the temperature of the air inside the tires increases, which causes the air pressure inside the tires to increase. If the temperature rises enough, a tire could blow out. Reducing the pressure inside the tires when you’re planning a long road trip on a hot day could help you avoid this.

Many foods are canned using pressure cookers. As the pressure in the sealed, heavy-walled cooker increases, the boiling point of water increases. The higher temperature kills bacteria that would remain at lower temperatures.

**Applying Critical-Thinking Skills**

**Directions:** Answer each question or respond to each statement.

1. **Infer** How would you adjust the pressure in car tires if you lived where temperatures were generally below freezing? Explain.

2. **Generalize** Use the kinetic molecular theory to explain why pressurized aerosol cans should be stored at room temperature rather than at very hot or very cold temperatures.

3. **Apply** Propane tanks used for outdoor barbecues contain a liquid under pressure. When the valve is opened, the pressure drops and the liquid changes to a gas that is used as a fuel to cook the food. People sometimes use a liquid crystal thermometer taped to the outside of the tank to determine how much gas is left in the tank. How would this work?
Gas Laws

You know that you can figure out how the volume of a gas changes when the pressure changes by using Boyle’s law. The equation for Boyle’s law is \[ V_2 = \frac{P_1 V_1}{P_2} \]

You can also figure out what happens to the volume of a gas when the temperature changes using Charles’ law. The equation for Charles’s law is \[ \frac{V_2}{V_1} = \frac{T_2}{T_1} \]

Formulate an Equation

What happens to the volume when the temperature and pressure of a gas change at the same time? In the space below, combine Boyle’s law and Charles’s law into a single equation that you can use to figure out what happens to the volume of a gas when the temperature and pressure of the gas change.
Design an Experiment to Collect Data

In this chapter, you have learned about the relationship between the motion of particles in matter and change of state. How might you use your knowledge of particles in real life? Suppose that you work for a state highway department in a cold climate. Your job is to test three products. You must determine which is the most effective in melting existing ice, the best at keeping melted ice from refreezing, and the best product to buy.

Question
How can you compare the products? What might make one product better than another? Consider how you can describe and compare the effect of each product on both existing ice and the freezing point of water. Think about controls, variables, and the equipment you have available.

Materials
- triple-beam balance
- beakers
- 50-mL graduated cylinders
- thermometers
- distilled water
- test tubes
- Also needed: ice, salt

Safety

Procedure

1. Read and complete a lab safety form.
2. Write a set of procedures you will use to answer your questions.
   - Include the materials and steps you will use to test the effect of each product on existing ice and on the freezing point of water.
   - How will you record your data? Draw any data tables, such as the example on the next page, that you might need.
   - Have your teacher approve your procedures.
3. Begin by observing and recording your observations on how each product affects ice. Does it make ice melt or melt faster?

4. Test the effect of each product on the freezing point of water. Think about how you will ensure that each product is tested in the same way.

5. Add any additional tests you think you might need to make your recommendation.

**Lab Tips**
- To ensure fair testing, add the same mass of each product to the ice cubes at the same time.
- Be sure to add the same mass of each solid to the same volume of water. About 1 g of solid in 10 mL of water is a good ratio.
- Keep adding crushed ice/salt slush to the cup so that the liquid in the test tubes remains below the surface.

**Analyze and Conclude**
6. **Analyze** the data you have collected. Which product was most effective in melting existing ice?

   How do you know?
Lab A continued

7. Determine which product was most effective in lowering the freezing point of water.

8. Draw or make a model to show the effect of dissolved solids on water molecules.

9. Cause and Effect In terms of particles, what causes dissolved solids to lower the freezing point of water?

10. Draw Conclusions In terms of particles, why are some substances more effective than others in lowering the freezing point of water?

11. The Big Idea Why is the kinetic molecular theory important in understanding how and why matter changes state?

Communicate Your Results
You are to present your recommendations to the road commissioners. Create a graphic presentation that clearly displays your results and justifies your recommendations about which product to buy.
Design an Experiment to Collect Data

In this chapter, you have learned about the relationship between the motion of particles in matter and change of state. How might you use your knowledge of particles in real life? Suppose that you work for a state highway department in a cold climate. Your job is to test three products. You must determine which is the most effective in melting existing ice, the best at keeping melted ice from refreezing, and the best product to buy.

Question
How can you compare the products? What might make one product better than another? Consider how you can describe and compare the effect of each product on both existing ice and the freezing point of water. Think about controls, variables, and the equipment you have available.

Materials
- triple-beam balance
- beakers
- 50-mL graduated cylinders
- thermometers
- distilled water
- test tubes

Also needed: ice, salt

Safety

Procedure

1. Read and complete a lab safety form.

2. Write a set of procedures you will use to answer your questions. Include the materials and steps you will use to test the effect of each product on existing ice and on the freezing point of water. How will you record your data? On the next page, draw any data tables that you might need. Have your teacher approve your procedures.

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________

________________________________________________________________________
3. Begin by observing and recording your observations on how each product affects ice. Does it make ice melt or melt faster?

4. Test the effect of each product on the freezing point of water. Think about how you will ensure that each product is tested in the same way.

5. Add any additional tests you think you might need to make your recommendation.

**Lab Tips**
- To ensure fair testing, add the same mass of each product to the ice cubes at the same time.
- Be sure to add the same mass of each solid to the same volume of water. About 1 g of solid in 10 mL of water is a good ratio.
- Keep adding crushed ice/salt slush to the cup so that the liquid in the test tubes remains below the surface.

**Analyze and Conclude**
6. **Analyze** the data you have collected. Which product was most effective in melting existing ice? How do you know?

7. **Determine** which product was most effective in lowering the freezing point of water.
Lab B continued

8. **Draw** or make a model to show the effect of dissolved solids on water molecules.

9. **Cause and Effect** In terms of particles, what causes dissolved solids to lower the freezing point of water?

10. **Draw Conclusions** In terms of particles, why are some substances more effective than others in lowering the freezing point of water?

11. **The Big Idea** Why is the kinetic molecular theory important in understanding how and why matter changes state?

**Communicate Your Results**
You are to present your recommendations to the road commissioners. Create a graphic presentation that clearly displays your results and justifies your recommendations about which product to buy.

**Inquiry Extension**
In some states, road crews spray liquid deicer on the roads. If your teacher approves, you may test liquids such as rubbing alcohol, corn syrup, or salad oil.
Investigating the Effect of Deicers on the Environment

Directions: Use the information and data from the Lab Design an Experiment to Collect Data to perform this lab.

You have learned that some materials work better than others for deicing roadways or for keeping ice from forming. In Lab B you investigated several products for their deicing ability and chose the one that performed the best. Deicers are used often in cold climates and can build up on roadways and roadsides. They can cause damage to plants, cars, roads, and nearby bodies of water. Design a procedure to investigate the effect of deicer products on natural resources, vehicles, or roadways. Then consider the results from Lab B. Would you change your mind about which is the best product to buy?

Please note that you must complete Lab B before beginning Lab C. Also, have your teacher approve your design and safety procedures before beginning your experiment.
**States of Matter**

**End-of-Chapter Practice**

**Directions:** Work with a partner to create a plan for an animated website that explains the properties of solids, liquids, and gases and the changes in state that can occur.

Use a diagram such as the one at the right, or create a diagram of your own.

**Your diagram should:**

- compare the solid, liquid, and gas states of matter by shape, volume, arrangement, and by movement of particles;
- explain the different changes in state that can happen.

Consider creating a website in which the user can click on part of the diagram to get more information. You can include words, pictures, and videos—whatever you think will best explain the key ideas.

- With your partner, brainstorm ideas about what to include on your animated website.

- Create your diagram and share it with the class.

**Our diagram will look like:**

<table>
<thead>
<tr>
<th>Individual responsibilities:</th>
</tr>
</thead>
</table>

**Web Site Animation Requirements**

- clear use of explanations and appropriate diagrams
- imaginative use of animation
- everyone in the group participates