Chemistry

Unit 5: The Chemistry of Climate Change

Workbook 1

Name: ______________________________ Period: ______

Workbook 5.1 Date:

Guiding Question:

Do Now:

Important Definitions and Equations:

Notes:

There are multiple different temperature scales that you will encounter in this class. In the U.S. we use the Fahrenheit scale whereas most of the rest of the world uses Celsius.

Comparing Fahrenheit and Celsius:

- Fahrenheit – mp of water is 32 °F and bp of water is 212 °F
- Celsius – mp of water is 0 °C and bp of water is 100 °C

Degree: ____
____.

There are 180 Fahrenheit degrees between 0 °C and 100 °C. This means that a Fahrenheit degree unit is a smaller change in temperature than a Celsius degree unit.

- This is why the formula to convert between the two values contains a fraction:

On the Celsius scale, the temperature at which the volume of a gas is theoretically equal to 0 is -273 °C. This value is equal to 0 K. 0 K is referred to as _____________. It is the lowest possible temperature as volume can never be _________________.

The scientific community will typically record temperature in Kelvins because the scale contains no negative numbers and can thus be used in ______________________ (we'll discuss this later)

Comparing Celsius and Kelvin:

If you need to convert from F to K, you will need to convert to F to C first.

Response:

1 Hot Enough
Thermometers

Purpose

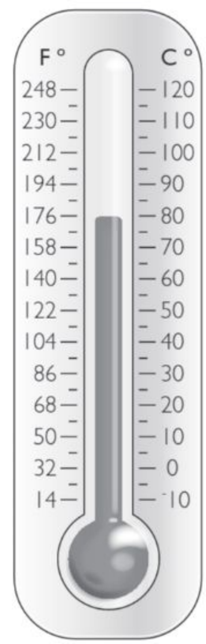
To introduce the three commonly used temperature scales and learn how to convert between them.

Part 1: Fahrenheit and Celsius

Read this: In 1724, German physicist Daniel G. Fahrenheit invented the mercury thermometer. To set his scale, he called the temperature of an ice/salt mixture 0° and called his own body temperature 96°. He then divided his scale into degrees.

In 1747, Swedish astronomer Anders Celsius created a thermometer that used a different scale. He set 0° to be the melting point of snow and 100° to be the boiling point of water. When he split his scale into degrees, each degree represented a larger change in temperature than Fahrenheit's degrees. 1°F does **not** equal 1°C.

1. The Fahrenheit and Celsius scale are shown here side by side:
   - **a.** What is the temperature of the room in degrees Celsius? ______ Fahrenheit? ______ (check the thermostat at the front of the room)
   - **b.** What is a healthy body temperature in Celsius? ______ Fahrenheit? ______
   - **c.** Which is hotter, 30°C or 30°F? Explain your reasoning.
   - **d.** Estimate what 50°C would be on the Fahrenheit scale.
   - **e.** The formula for converting from degrees Celsius to degrees Fahrenheit is $F = \frac{9}{5}(C) + 32$. Check your answer from part d by performing the calculation. Show your work.



2. It is going to be 35°C today, what should you wear? Support your answer by converting the temperature to Fahrenheit.

3. Water boils at 100°C, how hot is that in degrees Fahrenheit?

4. A comfortable room temperature is around 70°F. What is this temperature in °C?

Workbook 5.1 Date:

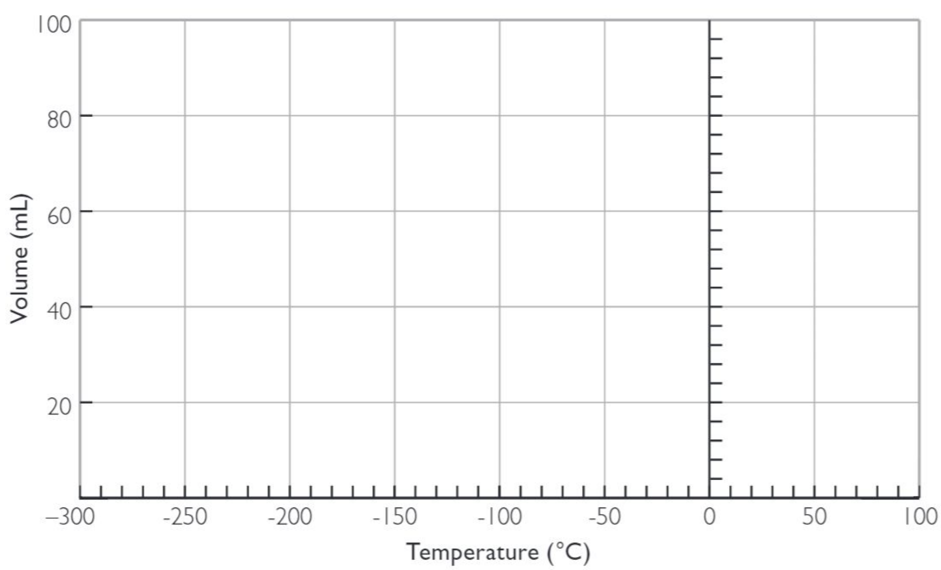
Part 2: The Kelvin Scale

Read This: Thermometers work because the volume of matter changes in response to changes in temperature. Matter generally expands when heated (because molecules start moving more quickly and spread out from one another) and contracts when cooled (because molecules slow down and can get closer together). In a thermometer, as the liquid is heated it expands and moves up the barrel of the thermometer. As the liquid cools, it contracts and moves down the barrel.

1. The volume of a sample of gas was measured at several temperatures. The data are given in the table below. Plot the data points on the graph.

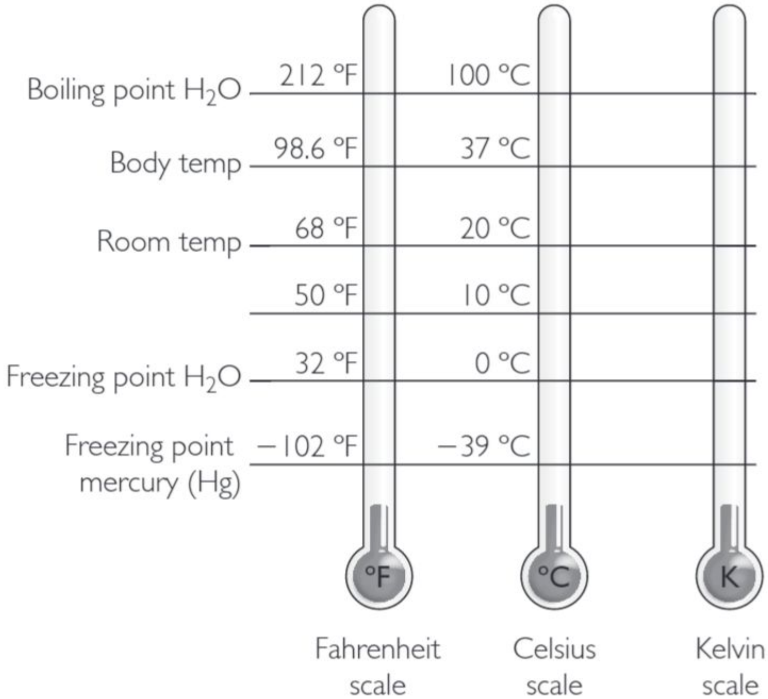
Temperature	Volume
10.0 °C	50 mL
50.0 °C	57 mL
100.0 °C	66 mL

Volume Versus Temperature in °C



2. Draw the best straight line you can through the points on the graph.
3. Use the graph to find the temperature if the volume of this gas decreased to zero. __________°C.
4. Do you think the temperature can keep dropping indefinitely? Explain your reasoning.

5. Compare the Fahrenheit, Celsius, and Kelvin thermometers on the next page. Fill in the temperatures in Kelvin that correspond to the temperatures shown on the Fahrenheit and Celsius thermometers. Since the Kelvin scale was based off of the Celsius scale, the size of the degrees are the same, but they have a different start point. 0°C = 273 K.



6. Zero Kelvin (0K) is called **absolute zero**. What is absolute zero in degrees Celsius and degrees Fahrenheit?

Guiding Question:	
Do Now:	
Important Definitions and Equations:	**Notes:** Pressure: Volume: Temperature: Check-in
Response:	

2 Blow 'Em Up!

Investigating Pressure, Temperature and Volume

Purpose

To gain an understanding of pressure and volume, and the relationship between pressure, volume, and temperature.

Materials

- Large, Black garbage bag
- Plastic Straws (3-4)
- Duct Tape
- Scissors

Procedure

1. Tape the open end of the bag closed (teacher may have done this for you)
2. Using a pair of scissors, cut 3-4 small holes (one for each member of the group, minus one; if you have 4 people, you will cut 3 holes) along the edges of the bag. Be careful to not cut through both layers of the bag.
3. Insert a straw into each hole. Seal shut with duct tape.
4. Have one person lay down on the bag. This is to be done on the floor.
5. All other people are to take position around the bag at a straw and start blowing the bag up.
6. Keep blowing the bag up until (1) it pops or (2) no more air can be put in the bag (must have teacher approval to stop)
7. Record observations in the table below.

Data/Observations - Complete the table below. ***Write*** what you observed in the top row and ***draw*** a particle model of what is happening *before* inflating, *during* inflation and *after* you finish and allow it to deflate in the bottom. Include arrows for particle movement, labels for all parts of drawing, and temperature indications (cool, cold, warm, hot) for each drawing.

Before	During	After

Workbook 5.1 Date:

Questions

1. Before beginning the lab, did you think that you would successfully blow up your classmate? Explain your answer.

2. Using your current understanding of pressure, volume, and temperature explain why the gases from your breath could inflate the bag and lift your classmate.

3. After you let the air out of the bag, did the bag feel hot or cold? Why do you think that happened?

4. Explain what would happen to a sealed bag of chips if you travel into the mountains. (Pressure outside the bag decreases, but the inside stays the same; what may happen because of that?)

5. During the first shift in weather in the fall, temperatures in the morning become significantly cooler and the pressure gauge on your (or your parents') car comes on for a low-pressure warning. Using the idea of pressure, volume, and temperature, explain why you think this may happen.

Workbook 5.1 Date:

Guiding Question:

Do Now:

Important Definitions and Equations:	**Notes:**
	Over the next few days we will be looking at the relationship between different gas variables. Some will be directly proportional and some will be indirectly proportional. ● <u>Directly proportional</u> ● <u>Inversely proportional</u> <u>Charles's Law</u>: Because volume is proportional to temperature, the graph of volume versus temperature is a straight line that goes through the origin, (0,0). ● 0 volume = 0 degrees is only true using the _______________. **Thus, when we are using Charles's Law or any other gas law we must use temperature values in Kelvin.**

Response:

3 Sorry Charlie

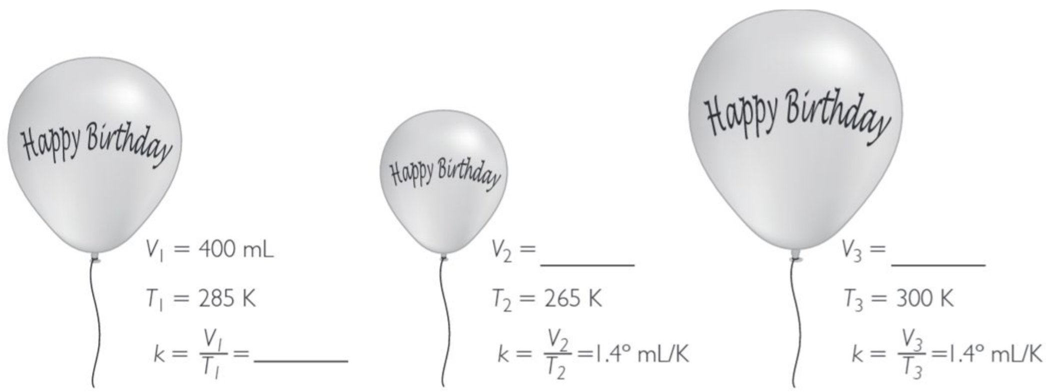
Charles' Law

Purpose

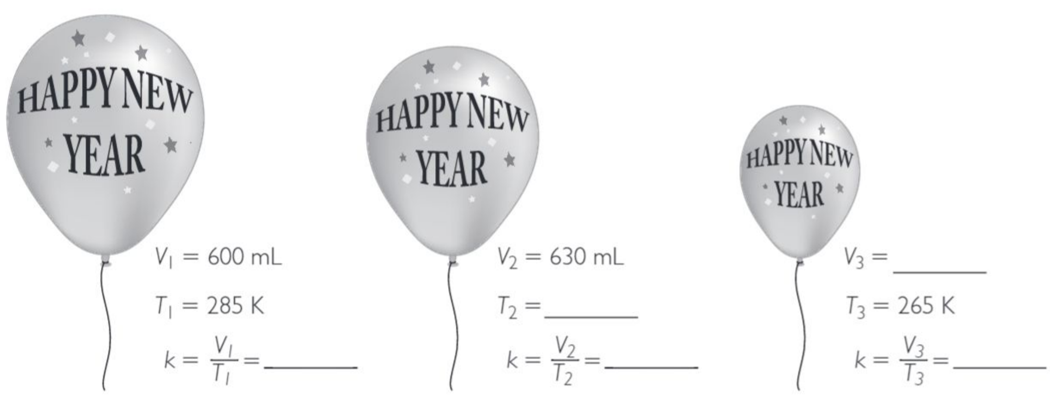
To calculate changes in the volume of a gas as they relate to temperature changes

Questions

1. A Happy Birthday balloon is filled with three breaths of air. It has an initial volume, V_1, of 400 mL at the initial temperature, T_1, of 285 K. The air in the balloon is cooled to 265 K and the volume decreases. Next, the air in the balloon is heated to 300 L and the volume increases. Calculate the missing values for the birthday balloon.



2. A New Year's balloon is inflated with five breaths of air. It has an initial volume of 600 mL at 285 K. It is heated to a temperature that changes the volume of air in the balloon to 630 mL. Next the air in the balloon is cooled to 265 K. Calculate the missing values for the New Year's balloon.

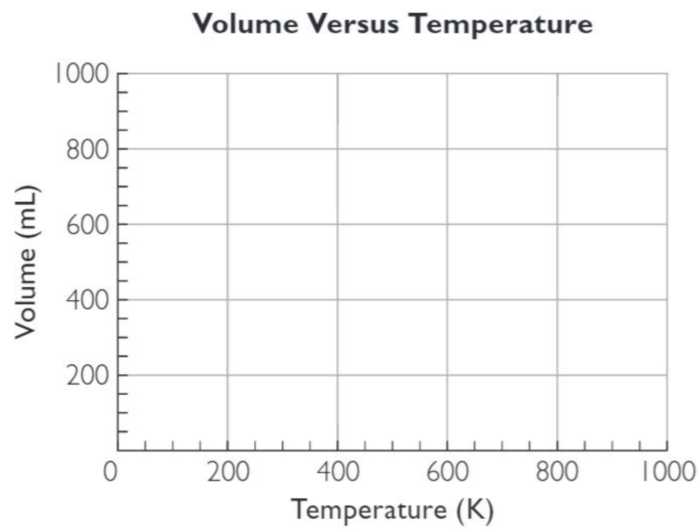


3. The volume of a sample of gas is proportional to its temperature in kelvins, but the volume is *not* proportional to its temperature in degrees Celsius. Use data from question 1 to provide evidence to support this assertion.

$T_1 =$ $T_2 =$ $T_3 =$

$k = V_1/T_1 =$ $k = V_2/T_2 =$ $k = V_3/T_3 =$

4. Plot volume versus temperature in kelvins for the Happy Birthday balloon and the New Year's balloon on the graph. Label each line.



5. Use the graph to find the approximate volume of the Happy Birthday balloon and the New Year's balloon at a temperature of 400 K.

6. Why do you think that the Happy Birthday balloon has a different proportionality constant, k, than the New Year's balloon?

Problem Solving

7. The beginning volume of gas is 500 mL at 20°C. The temperature is raised to 35°C. What is the new volume of the gas?

8. **Making Sense** Supposed you have a Valentine's Day balloon with a volume of 300 mL at 300 K.
    a. Is the proportionality constant larger or smaller than for the birthday balloon?

    b. At the same temperature, which balloon is smaller, the Valentine's Day balloon or the New Year's balloon?

9. **Going Deeper** On the graph of volume versus temperature for a gas, what does the slope of the line relate to?

Guiding Question:

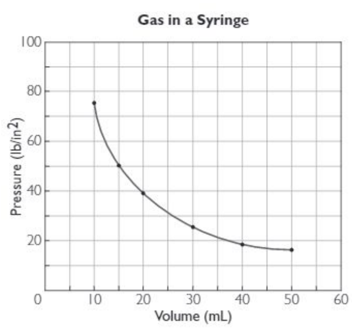
Do Now:

Important Definitions and Equations:

Notes:

The model simulated the Kinetic Theory of Gases which states:

<u>Boyle's Law</u>:



For small volumes, pressure is ___________________

For large volumes, pressure is ___________________

Response:

4 Show Me Your Moves

Kinetic Molecular Theory

Purpose

To describe the behavior of gas molecules and discover what causes pressure.

Questions

1. Observe the gas particles computer simulation. List at least four features of the model.

Example: The particles are in constant motion

2. What causes the gas particles to change direction in the model?

3. What do you notice about the speeds of the particles in the model?

4. What do you observe when the temperature changes in the model?

5. **Making Sense** How can you use the motions of gas particles to explain why gases expand on heating and contract on cooling? Draw a picture to explain your answer.

6. **Going Beyond** Which is denser, air at 10°C or air at 4°C? Explain your reasoning. Why does hot air rise?

5 Boyle's Law

Pressure-Volume Relationship

Purpose

To determine the relationship between pressure and volume of the gas and to use that relationship to predict the pressure at other volumes.

Materials

LabQuest
Vernier Gas pressure sensor
20 mL syringe

Procedure

1. Look at the powerpoint slide for directions; directions are also at your lab station.

Data and Calculations

Volume (mL)	Pressure (kPa)	Constant, k

Processing the Data

1. What experimental factors are assumed to be constant in this experiment?

2. Identify the independent and dependent variable in this experiment.

3. With the best-fit curve still displayed, choose Interpolate from the Analyze menu. A vertical cursor now appears on the graph. The cursor's volume and pressure coordinates are displayed in the floating box. Move the cursor along the regression line until the volume value is 5.0 mL. Note the corresponding pressure value. Now move the cursor until the volume value is doubles (10.0 mL). What does you data show happen to the pressure when the volume is *doubled*? Use the pressure values in your answer.

4. Using the same technique as in question 1, what does your data show happens to the pressure if the volume is *halved* from 20.0 mL to 10.0 mL? Use the pressure values in your answer.

5. Use the same technique as in question 1, what does your data show happens to the pressure if the volume is *tripled* from 5.0 mL to 15.0 mL? Use the pressure values in your answer.

6. From your answers to the first three questions *and* the same of the curve in the plot of pressure vs. volume, do you think that the relationship between the pressure and volume of a confined gas is direct or inverse? Explain your answer.

7. Based on your data, would you expect the pressure to be if the volume of the syringe was increased to 40.0 mL? Explain or show work to support your answer.

8. Based on your data, what would you expect the pressure to be if the volume of the syringe was decreased to 2.5 mL? Explain or show work to support your answer.

9. One way to determine if a relationship is direct or inverse is to find a proportionality constant, k, from the data. If this relationship is direct, $k = P/V$. If it is inverse, $k = P \bullet V$. Based on your answer to question 6, choose one of these formulas and calculate k for the seven ordered pairs in your data table. Show the answers in the third column of the Data and Calculations table.

10. How *constant* were the values of k you determined? Good data may show some variation because no data collection tool is perfect, but the values of k should be relatively constant.

11. Using P, V, and k, write an equation representing Boyle's Law (hint: it's one of the two equations in question 9). Then, write a verbal statement that correctly expresses Boyle's Law.

Guiding Question:	
Do Now:	
Important Definitions and Equations:	**Notes:** Gay-Lussac's Law: The three gas laws help predict gas temperature, pressure, and volume when two of these variables change and the third remains fixed. In all cases, the amount of gas cannot change. Check-In:
Response:	

6 Gay Lussac's Law

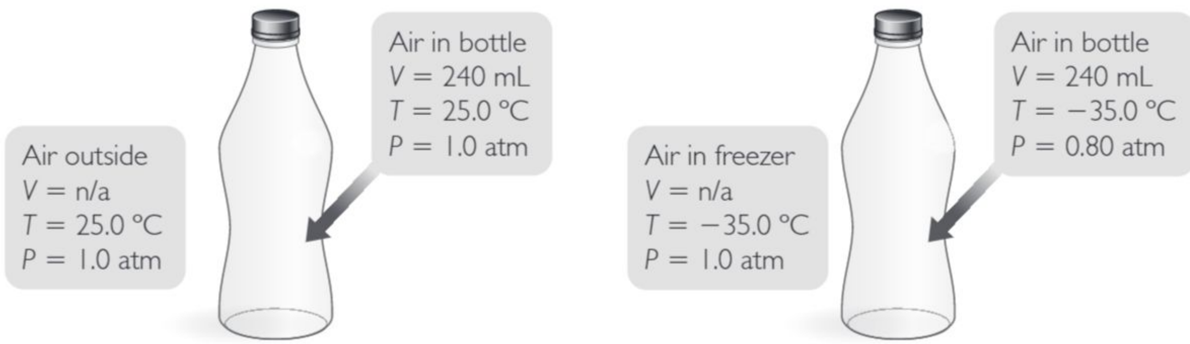
Pressure-Temperature Relationship

Purpose

To examine how gas pressure changes in flexible and rigid containers

Part 1: Glass Bottle (Rigid Container)

The air trapped inside a 240 mL glass bottle has a pressure of 1.0 atm and a temperature of 25.0°C. You put the glass bottle into a freezer. After several hours, the air trapped inside the bottle has a temperature of -35.0°C and a pressure of 0.80 atm.



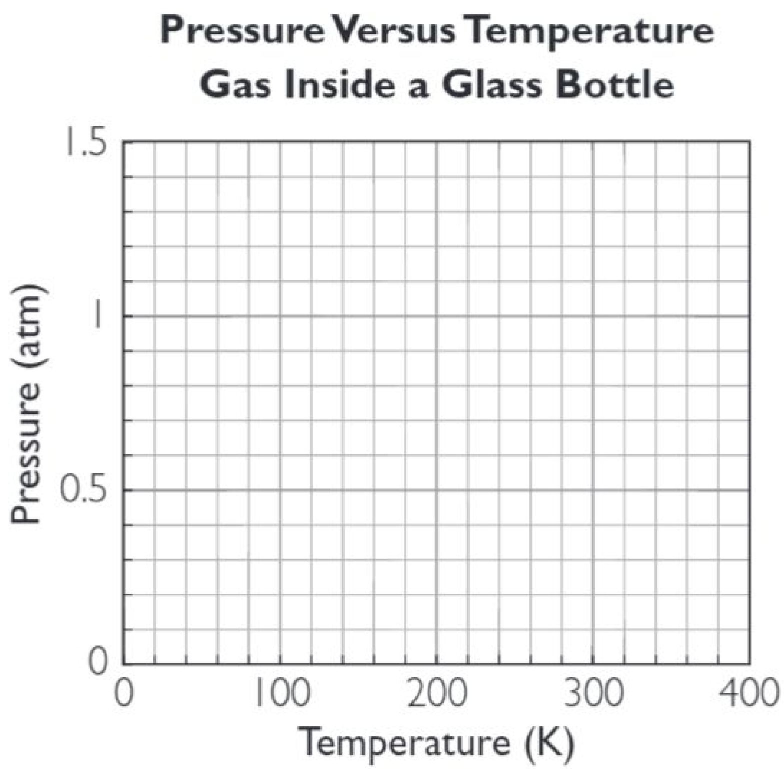
1. When the glass bottle is put into the freezer, how does the air trapped inside the bottle change? How is it the same?

2. Determine the value for k for the air trapped inside the glass bottle before and after cooling to show that P equals kT.

3. The table shows data for the glass bottle in four locations. The atmospheric pressure stays unchanged at 1.0 atm, but the temperature is different at each location.
   a. Complete the table.

Air Outside the Bottle			Air Inside the Bottle			
V(mL)	**T(K)**	**P(atm)**	**V(mL)**	**T(K)**	**P(atm)**	**P/T**
N/A	200 K	1.0 atm	240 mL	200 K	0.67 atm	
N/A	238 K	1.0 atm	240 mL	238 K	0.80 atm	
N/A	298 K	1.0 atm	240 mL	298 K	1.0 atm	
N/A	400 K	1.0 atm	240 mL	400 K	1.34 atm	

b. Plot pressure versus temperature for the air trapped inside the glass bottle at each location. Draw the best fit line through the data points to determine the pressure inside the glass bottle if the temperature is 350 K.



4. A sample of chilled air from a freezer is sealed up inside a glass bottle with a volume of 240 mL. This bottle is then allowed to warm to room temperature. What is the air pressure inside the bottle at 25°C? Show your work.

Air in the bottle in the freezer

P_1	1.0 atm
T_1	−35 °C
V_1	240 mL

Air in the bottle in the room

P_2	—?—
T_2	25 °C
V_2	240 mL

Part 2: Car Air Bag (Flexible Container)

Identical air bags inflate in two different cars. One car is at sea level, and the second car is in the mountains. The temperature, pressure, and volume of the air outside the bag and of the gas inside the bag are given in the table.

	Air at sea level	Gas in airbag at sea level	Air on mountain	Gas in airbag on mountain
V	–	60.0 L	–	86.0 L
T	25.0 °C	25.0 °C	25.0 °C	25.0 °C
P	1.0 atm	1.0 atm	0.70 atm	0.70 atm

1. Consider the gas trapped inside the air bag. How do the volume, pressure, and temperature of the gas change as you go from sea level to the mountaintop?

2. Why is the volume of the air bag different in the two locations?

3. Show that the pressure of the gas in the air bag is inversely proportional to the volume of the gas in the air bag (Boyle's Law).

4. A different car has an air bag that inflates to 60 L on the mountaintop, where the air pressure is 0.70 atm and the temperature is 25°C. What volume will this air bag have at sea level?

Mountaintop

P_1	0.70 atm
T_1	25 °C
V_1	60.0 L

Sea level

P_2	1.0 atm
T_2	25 °C
V_2	—?—

5. **Making Sense** Compare a rigid container, such as the glass bottle, with a flexible container, such as an air bag. Describe how the type of container affects how the pressure of the gas inside the container can vary.

Guiding Question:	
Do Now:	
Important Definitions and Equations:	**Notes:**
Response:	

7 Be the Molecule

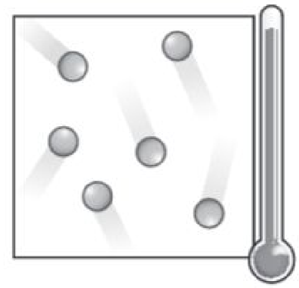
Molecular View of Pressure

Purpose

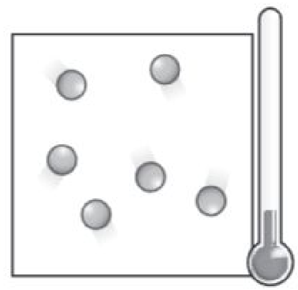
To examine how the motions of gas molecules cause pressure

Part 1: Computer Simulations

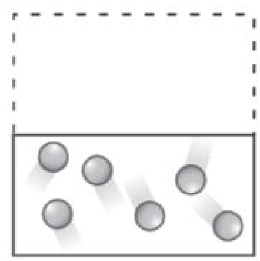
1. For the first simulation, the volume does not change. Focus on what happens to the gas pressure as the temperature changes.
    a. What happens to the pressure when the temperature is increased? Explain why.



    b. What happens to the pressure when the temperature is decreased? Explain why.

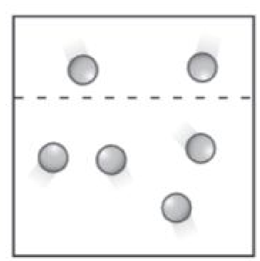


2. For the second simulation, the temperature does not change. Focus on what happens to the pressure as the volume of the container changes.
    a. What happens to the pressure when the volume is decreased? Explain why.



    b. What happens to the pressure when the volume is increased? Explain why.

3. What conditions result in more collisions of molecules with the walls of the container and with one another?



4. Name two ways you could reduce the pressure of a gas sample.

Part 2: Gas Law Review

1. **Fill in the tables.** The first line of the table gives the volume, pressure, and temperature for a container of gas. The gas has an initial volume of 22.4 L. The pressure is 1.0 atm, and the temperature is 300 K. Each subsequent row represents a new set of conditions for this gas. Fill in the blank spaces.

a.

Volume	Pressure	Temperature	Gas law
$V_1 = 22.4$ L	$P_1 = 1.0$ atm	$T_1 = 300$ K	(initial conditions)
	1.0 atm	150 K	Charles's law
44.8 L	1.0 atm		Charles's law
	1.0 atm	1200 K	

b.

Volume	Pressure	Temperature	Gas law
$V_1 = 22.4$ L	$P_1 = 1.0$ atm	$T_1 = 300$ K	(initial conditions)
	2.0 atm	300 K	
	0.5 atm	300 K	
89.6 L		300 K	

c.

Volume	Pressure	Temperature	Gas law
$V_1 = 22.4$ L	$P_1 = 1.0$ atm	$T_1 = 300$ K	(initial conditions)
22.4 L		150 K	
22.4 L		600 K	
	4.0 atm	1200 K	

2. **Making Sense** In your own words, explain what gas pressure is and how it can be changed.

Guiding Question:	
Do Now:	
Important Definitions and Equations:	**Notes:**
Response:	

8 What Goes Up

Combined Gas Law

Purpose

To explore what happens when the temperature, pressure, and volume of a gas all change at the same time.

Tracking the Volume of a Weather Balloon

A weather balloon is filled to a volume of 12,500 L at sea level. The air pressure is 1.0 atm and the temperature is 298 K. These starting values are listed in the bottom row of the table. ***<u>Do not fill in the table yet</u>***.

Altitude (ft)	Temperature (°C)	Temperature (K)	Pressure (atm)	Volume (L)
40,000 ft	−57 °C		0.20 atm	
30,000 ft	−45 °C	228 K	0.30 atm	33,000 L
25,000 ft	−35 °C		0.40 atm	
10,000 ft	−5 °C		0.70 atm	
5,000 ft	5 °C		0.80 atm	
0 ft	17 °C	290 K	1.0 atm	12,500 L

1. What is the value of PV/T at the starting conditions (0 ft)?

2. **Example**: The balloon is released and travels to an altitude of 5,000 ft. Here is how the value of PV/T can be used to calculate the volume of the balloon under these new conditions:

$$k = \frac{P_1V_1}{T_1} = \frac{(1.0\text{ atm})(12{,}500\text{ L})}{290\text{ K}} = 43\ \frac{\text{atm}\cdot\text{L}}{\text{K}}$$

$$k = \frac{P_2V_2}{T_2}$$

$$43\ \frac{\text{atm}\cdot\text{L}}{\text{K}} = \frac{(0.80\text{ atm})(V_2)}{278\text{ K}}$$

$$V_2 = 15{,}000\text{ L}$$

Write this new volume in the table.

3. Did the volume of the balloon increase or decrease when it rose to 5,000 ft? Explain why.

4. ***Calculate the rest of the values that are missing from the table. Fill in the table with your answers.***
5. What is the value of PV/T at sea level? At 25,000 ft? Explain why this number is useful in your calculations.

6. Suppose a second weather balloon is filled with 25,000 L of helium at 290 K and 1.0 atm. What is the value of the proportionality constant for this balloon?

7. **Making Sense** What happened to the volume of the balloon as it rose? What explanation can you offer for this?

8. Suppose a weather balloon is designed to burst when the volume expands to 40,000 L.
   - **a.** For a balloon filled at sea level with 12,500 L of helium, use the table to estimate the altitude at which the balloon will burst.
   - **b.** If this same balloon is filled at sea level with 25,000 L of helium, will it burst at the same altitude, a higher altitude, or a lower altitude than if it started with 12,500 L of helium. Support your answer with a calculation.