How do gases behave?

Why are we doing this?

Imagine buying a helium balloon for your friend's birthday. What will happen to the balloon if you take it outside on a hot summer day? What will happen if it is a cold winter day? What if more gas is added to the balloon? What if the volume of the balloon expands or contracts? Gases have a unique set of properties that can be observed and measured, and we can use the relationships between these properties to predict the answers to the questions raised above. In this activity, we will explore the relationships between five differ properties of a gas: pressure, temperature, amount, volume, and mass.

Your Learning Outcomes

You will be able to:

1. Describe how gases exert a pressure.
2. Calculate a one-step unit conversion between different measurements of pressure.
3. Describe and model the relationships between pressure, temperature, volume, amount, and mass.

The Plan

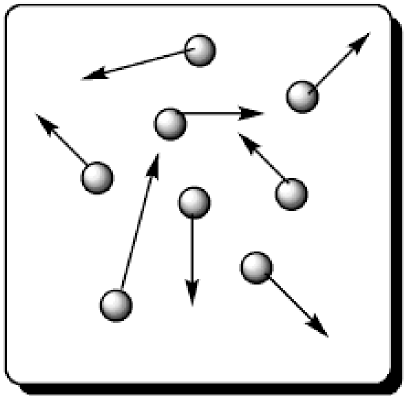
1. Assign roles*.
    a. ***Manage**r* – This person will keep the team on task and provide direction to the group. This person is responsible for uploading the group's work to Gradescope. Make sure you make a note of everyone in the group. You must add everyone's name when submitting your answers to Gradescope.
    b. ***Spokesperson*** – This person will represent the group be responsible for speaking for the group to the rest of the class.
    c. ***Recorder*** – This person will be responsible for recording the team's answers to the Critical Thinking Questions in an organized and coherent manner.
    d. ***Analyst*** – This person will be responsible for critical analysis of the team's work (i.e., the Devil's Advocate). This person should make sure everyone understands what is happening before the group moves forward.
2. Complete the Critical Thinking Questions as a group.
3. Submit your team's work via Gradescope. Groups may choose to work in a Word document or write out their answers on a separate sheet of paper. All work must be upload to Gradescope as a PDF file.

**Students may choose to complete this activity independently if they are unable to attend discussion due to illness or injury; in which case, the student must perform all roles and complete all aspect of the activity. To receive full credit, documentation as to the need for the absence from discussion must be included with the submission and your TA must be notified of the absence.*

Model 1: Particles in the Gas Phase

Consider the following assumptions that we make about the behavior of gases:

1. Gas molecules move constantly and randomly through the volume of the container they occupy at various speeds and in every direction.
2. The volume of individual molecules in a gas is negligible because their size is much smaller than the distance between gas molecules.
3. The forces of attractions and repulsions between molecules in a gas are negligible except when they collide with each other.
4. Gas molecules continually collide with each other and with the walls of the container. The collisions are *elastic*, which means that the kinetic energy of the colliding molecules does not change.
5. The kinetic energy of the gas molecules is proportional to the absolute temperature of the gas.



Critical Thinking Questions:

1. What assumptions are made regarding the size of molecules in a gas?
   The size of the gas particles is assumed to be zero (negligible) because the particles are so much smaller than the space between the particles and the size of the container.

2. What assumptions are made about the interaction between molecules of gas?
   It is assumed that there are no interactions between gas particles.

3. Are collisions between molecules of gas visualized more like collisions of sponges or collisions of billiard balls? Explain your answer.
   Billiard balls. It is assumed that when the particles collide that they bounce off of one another without losing energy.

4. What do the arrows in the model represent?
   The velocity of the particles

5. Why are the arrows different sizes and pointing in different directions?
   The particles are moving in all different directions and with different individual speeds (slower = shorter arrow; faster = larger arrow).

Information:

Pressure is defined as a measurement of the force exerted per unit area. The collision between of a gas particle and another object exerts a force on that object. The pressure of a gas can be measured in a lot of different ways. 1 atmosphere of pressure is the force exerted by the gases in the atmosphere on an object at sea level. The same pressure can be measured as 760 mmHg or 101.325 kPa or 760 torr or 14.6959 pounds per square inch. These are known as equivalencies because each measurement is equal to the others.

$$1 \text{ atm} = 760 \text{ mmHg} = 101.325 \text{ kPa} = 760 \text{ torr} = 14.6959 \, \frac{\text{lbs}}{\text{in}^2}$$

Model 2: Dimensional Analysis (One-Step Conversations)

Two equivalent units can be used to convert from one unit to another.

1 foot = 12 inches

Therefore,

$$\frac{1 \, foot}{12 \, inches} \quad \text{or} \quad \frac{12 \, inches}{1 \, foot}$$

We can use these ratios (also called **conversion factors**) to convert from one unit to the next.

Example 1: Convert 25 inches to feet.

$$\begin{array}{l|l} 15 \text{ in} & 1 \text{ ft} \\ \hline & 12 \text{ in} \end{array} = 1.25 \text{ ft}$$

Example 2: Convert 1.5 feet to inches.

$$\begin{array}{l|l} 1.5 \text{ ft} & 12 \text{ in} \\ \hline & 1 \text{ ft} \end{array} = 18 \text{ in}$$

Critical Thinking Questions:

6. Mathematically describe how Example 1 in Model 2 was calculated.
(15 x 1) / 12 = 1.25

7. Mathematically describe how Example 2 in Model 2 was calculated.
(1.5 x 12) / 1 = 18

8. The same conversion factor was used in both Examples 1 and 2. Why did Example 1 use feet on top and inches on the bottom while Example 2 used inches on the top and feet on the bottom?
The order of the conversation factor has to do with the initial given units. In order to cancel out one unit and convert to another, the unit to be cancelled must appear on the top and bottom.

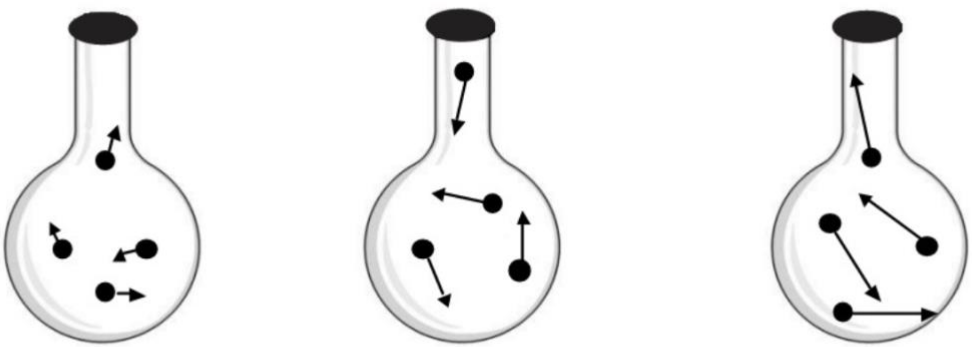
9. The atmospheric pressure in San Diego, CA is 101.3 kPa. Convert this measurement from kPa to atm using the information provide above.

$$101.3\ \text{kPa} \times \frac{1\ \text{atm}}{101.325\ \text{kPa}} = 0.9998\ \text{atm}$$

10. The atmospheric pressure in Denver, CO 615 mmHg. Convert this measurement into atm.

$$615\ \text{mmHg} \times \frac{1\ \text{atm}}{760\ \text{mmHg}} = 0.809\ \text{atm}$$

Model 3: Experiment A: Heating a gas.



A1	A2	A3
Volume = 1 unit	Volume = 1 unit	Volume = 1 unit
External pressure = 1 atm	External pressure = 1 atm	External pressure = 1 atm
Internal pressure = 1 atm	Internal pressure = 2 atm	Internal pressure = 3 atm
Temperature = 200 K	Temperature = 400 K	Temperature = 600 K

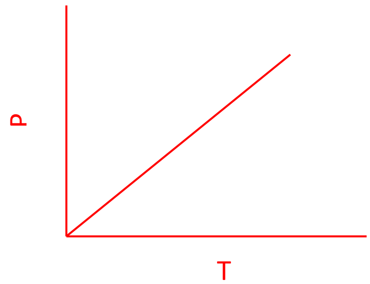
Critical Thinking Questions

11. In Experiment A, are any additional gas particles added or removed between experiments A1, A2, and A3?
No

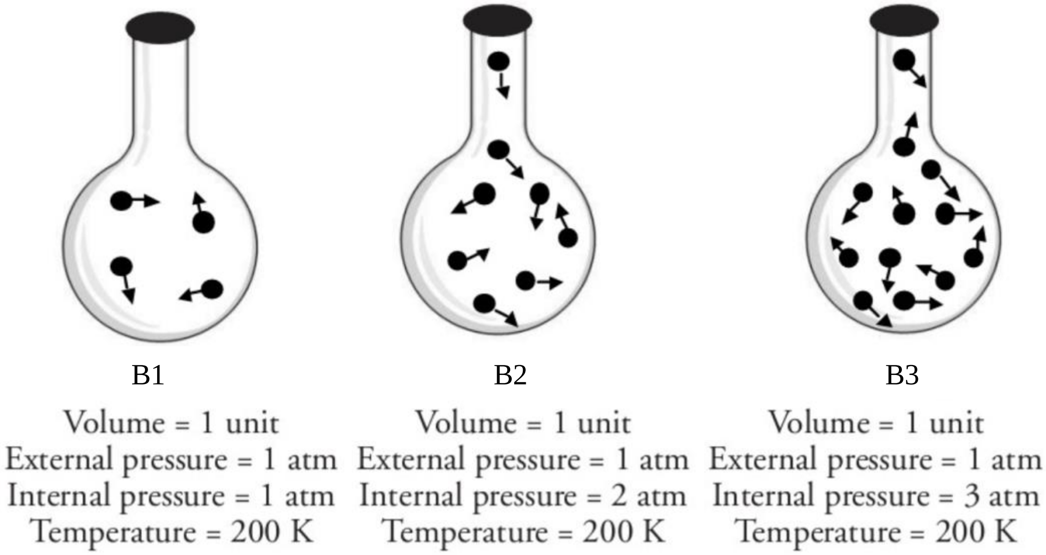
12. Does the volume of the container change between A1, A2, or A3?
No

13. Why is the length of the arrows in A3 longer than the arrows in A2 or A1?
Larger arrows mean the particles are moving faster due to the increase in temperature.

14. Graph the relationship between temperature and pressure. (Use temperature as the x-axis and pressure as the y-axis.)



Model 4: Experiment B: Adding more gas.

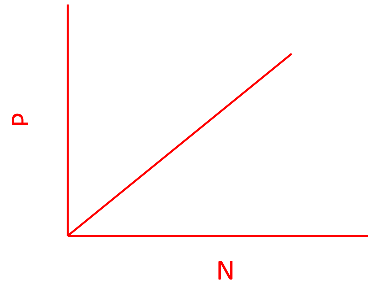


Critical Thinking Questions

15. In Experiment B, does the volume of the container change between B1, B2, or B3?
    No

16. Why do the length of the arrows remain the same in B1, B2, and B3?
    The particles are moving at the same velocity in all three conditions.

17. Graph the relationship between number of particles and pressure. (Use the number of particles as the x-axis and pressure as the y-axis.)



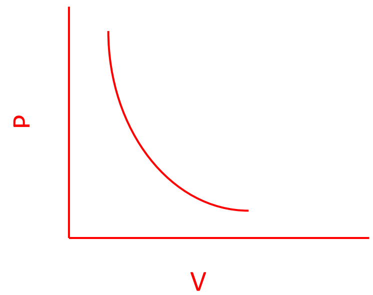
Model 5: Using the Interactive Simulation

Use the following simulation to conduct Experiments C and D:
https://chemicalthinking.xyz/idealgg/idealgg.html

Critical Thinking Questions

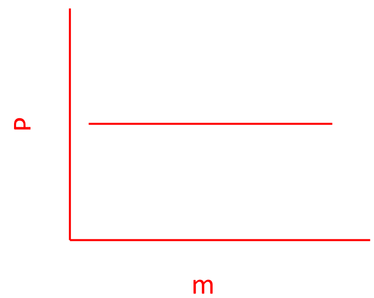
18. Experiment C examines the relationship between pressure and volume. Choose three different volumes for your container. Record the volume and pressure readings for each data point in the table below and then graph the relationship between volume and pressure. (Use the volume as the x-axis and pressure as the y-axis.) Answers will vary but the trend so be the same.

Trial	Volume	Pressure
C1	30	19.0
C2	60	7.2
C3	90	4.6



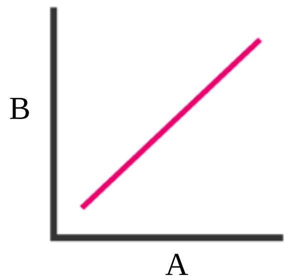
19. Experiment D examines the relationship between pressure and the mass of the gas particles. Choose three different masses for your container. Record the volume and pressure readings for each data point in the table below and then graph the relationship between volume and pressure. (Use the volume as the x-axis and pressure as the y-axis.) Answers will vary but the trend so be the same.

Trial	Mass	Pressure
D1	1	6.4
D2	3	6.4
D3	5	6.5



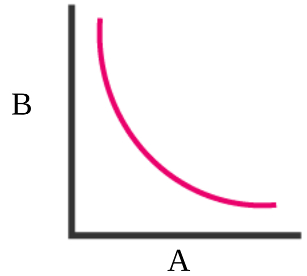
Information

A **directly proportional** relationship is one in which two variables change in the same manner. For example, when A increases, B also increases. This kind of relationship can be represented as follows:



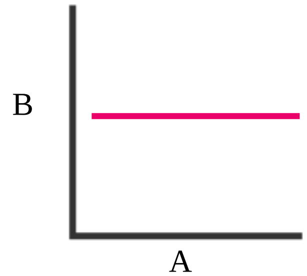
$\boxed{A \propto B}$

An **inversely proportional** relationship is one in which two variables change in opposite manners. For example, when A increases, B decreases. This kind of relationship can be represented as follows:



$A \propto \frac{1}{B}$

Two variables are said to be **independent** of one another when a change in one variable results in no change in the other. For example, when A increases, B does not change. This kind of relationship can be represented as follows:



$B \propto k$ (where k is a constant)

Critical Thinking Question

20. Describe the relationships between
    a. The pressure and the temperature of a gas.
    Directly proportional ($P \propto T$)

    b. The pressure and the amount of gas particles.
    Directly proportional ($P \propto N$)

    c. The pressure and the volume of a gas.
    Inversely proportional ($P \propto 1/V$)

    d. The pressure and the mass of the gas particles.
    Independent ($P \propto k$)