Investigation 1: What causes gas pressure?

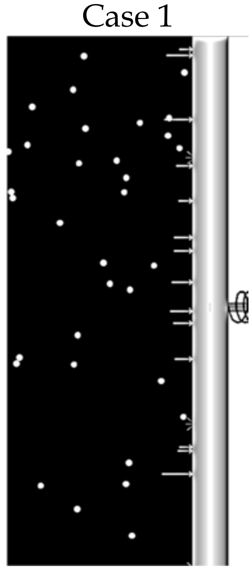
Every time a molecule collides with the piston, it exerts a force on it. The pressure (p) that the gas exerts on the piston is defined as the sum of all the molecular impact forces (F) on the surface area of the piston (A): $p = F/A$.

Run the model and make sure that molecules are shown by selecting the **Reveal** button. Observe the movement of molecules (you can hold down the **Trace** button to follow a single molecule). Then observe the collisions between the molecules with the piston while holding down the **Impact** button.

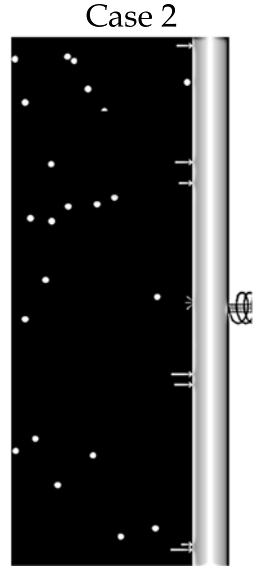
Answer the following questions:

a) The pictures below show two cases of the impacts of molecules on the piston.

Case 1



Case 2

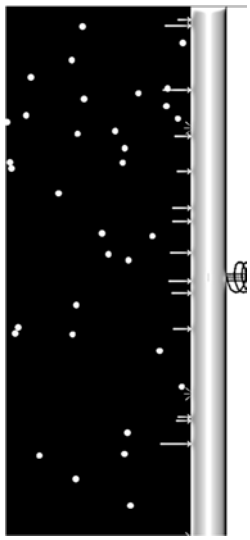


Based on your observations of the impulse (impact) arrows, in which case does the gas have a higher pressure?

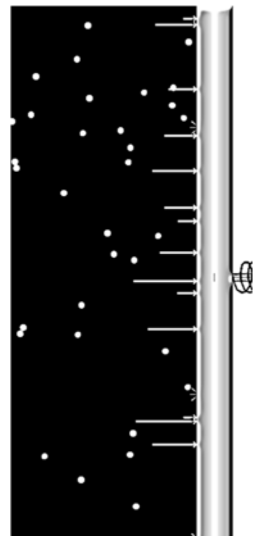
A. Case 1.
B. Case 2.
C. Both cases have the same pressure.
D. Cannot decide.

b) The pictures below show two different cases of the impacts of molecules on the piston.

Case 1



Case 2



Based on your observations of the impulse arrows, in which case does the gas have a higher pressure?

A. Case 1.
B. Case 2.
C. Both cases have the same pressure.
D. Cannot decide.

Investigation 2: Explore the relationship between number of molecules and the gas volume under the same pressure

In this experiment, you will add or remove molecules (just type A) using the plunger. Try several different numbers of molecules. **Keep the pressure constant** by locking the spring position with the metal pin. Also don't change the temperature.

Start the model and record the pressure and temperature, which will remain constant throughout the experiment:

Pressure: ________________________ Temperature: ________________________

Collect five data points

For each run:

- Change the number of molecules. Use amounts that are different by about 30. **Don't use fewer than 50 molecules**.
- Wait a few seconds for the piston to settle down.
- Press the **Show Average Values** button. The values will turn yellow and be averaged for as long as you hold the button down.
- When the average values become stable, record the number of molecules and the volume in the following table.
- Calculate the density (number of molecules divided by volume).

	Number of molecules	Volume	Density
1			
2			
3			
4			
5			

Does the density change a lot when the number of molecules changes?

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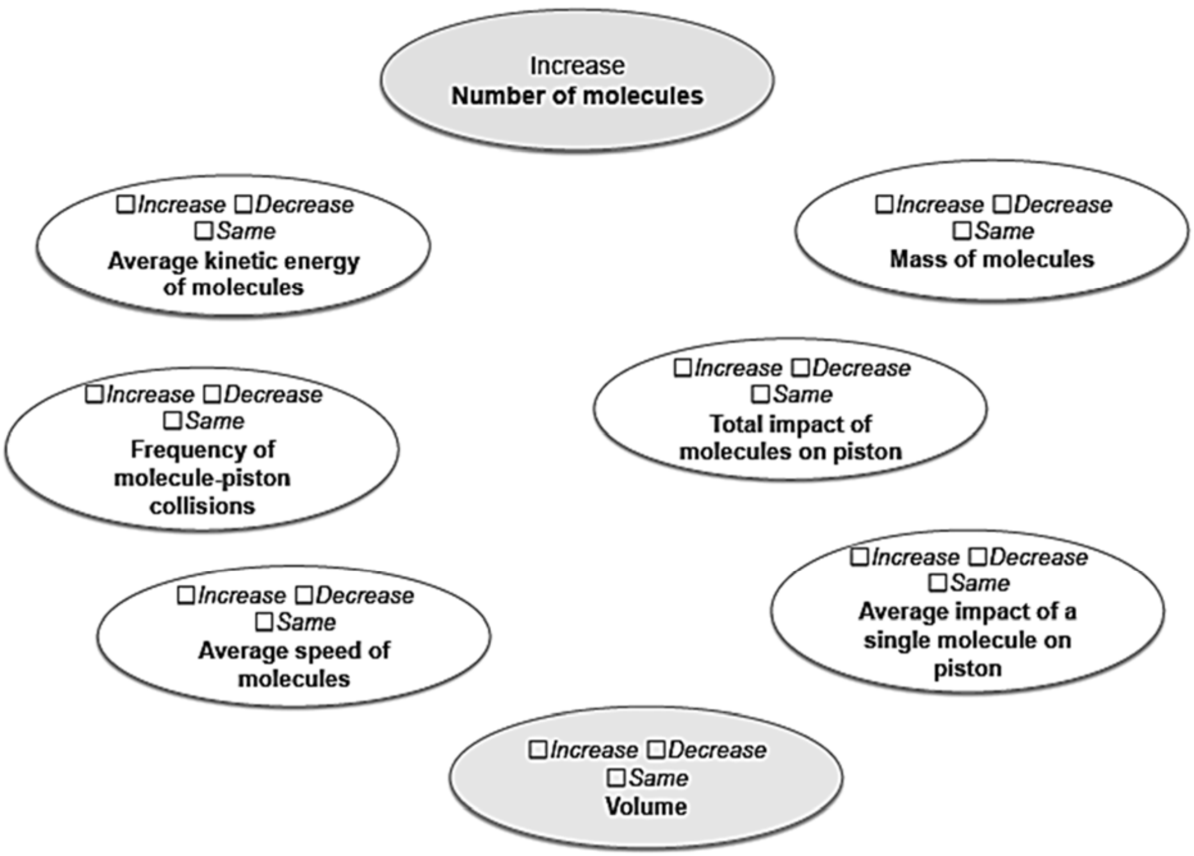
Molecular explanation

Run the model again. Slowly increase the number of molecules from 50 to 150 and carefully observe the movement of the molecules.

Based on your observation, **link the bubbles with arrows** to explain why increasing the number of molecules changes the volume. For each linked bubble, mark the correct box to indicate whether the corresponding property will increase, decrease, or remain the same. You can have more than one arrow coming out of or pointing to a bubble if necessary.

Use the arrows to show a chain of cause and effect



Investigation 3: Explore the relationship between number of molecules and gas pressure in the same volume

This experiment is similar to the previous one, except that you will now use the spring to pull or push the piston and try your best to **keep the volume constant at a value between 22 and 26** (instead of keeping the pressure constant).

Start the model and **begin with 50 molecules**. Record the temperature and volume, which will remain constant throughout the experiment:

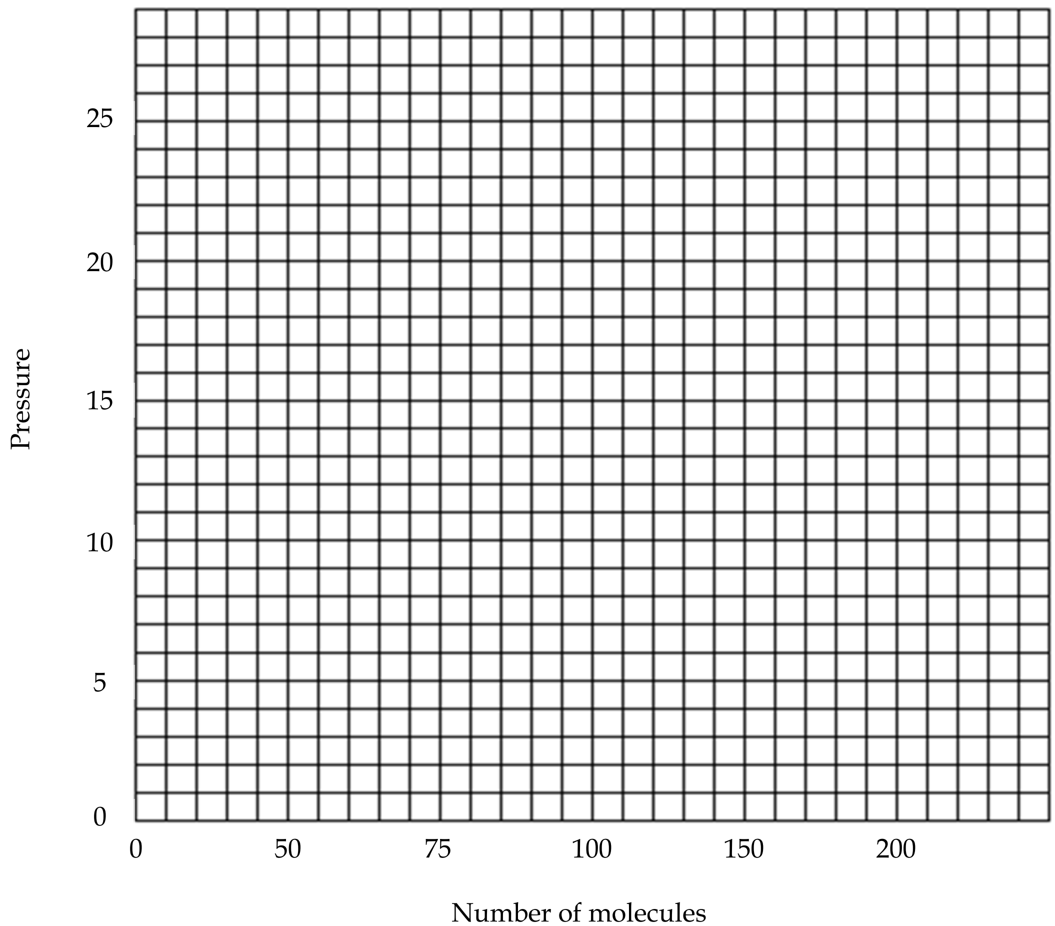
Temperature: ________________________ Volume: _______________________

Collect five data points

For each run:
- Increase the number of molecules. Use amounts that are different by about 30. **Don't use fewer than 50 molecules**.
- Push or pull on the spring to bring the volume to the original value. **Don't expect perfection! It's OK if the volume is within 0.5 of the original.**
- Wait a few seconds for the piston to settle down.
- Press the **Show Average Values** button. The values will turn yellow and be averaged for as long as you hold the button down.
- When the average values become stable, record the number of molecules and the pressure in the following table.

	Number of molecules	Pressure
1		
2		
3		
4		
5		

Graph pressure vs. number of molecules

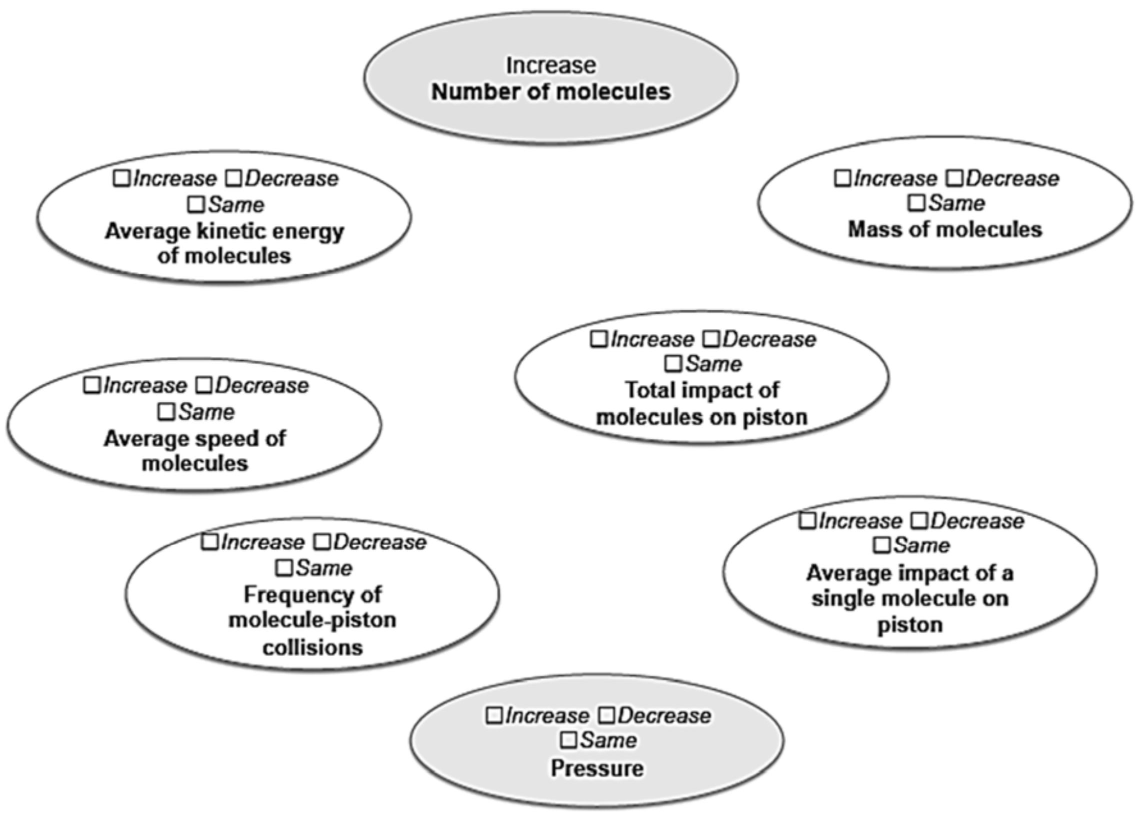


Molecular explanation

Run the model again. Slowly increase the number of molecules from 50 to 150 and carefully observe the movement of molecules. Pay attention to the differences in **the speeds of molecules**, **the impact of molecules on the piston**, and **the frequency of collisions of molecules with the piston**.

Based on your observation, **link the bubbles with arrows** to explain why increasing the number of molecules changes the pressure. For each linked bubble, mark the correct box to indicate whether the corresponding property will increase, decrease, or remain the same. You can have more than one arrow coming out of or pointing to a bubble if necessary.

Use the arrows to show a chain of cause and effect



Investigation 4: Explore the relationship between volume and pressure when the temperature does not change

In this experiment, you will push or pull the spring to change the volume of the gas. You can use the pin to lock the spring in various positions, which will give a steadier reading.

Start the model and record the temperature and number of molecules (**don't use fewer than 50 molecules**), which will remain constant throughout the experiment:

Temperature: ________________ Number of Molecules: _____________

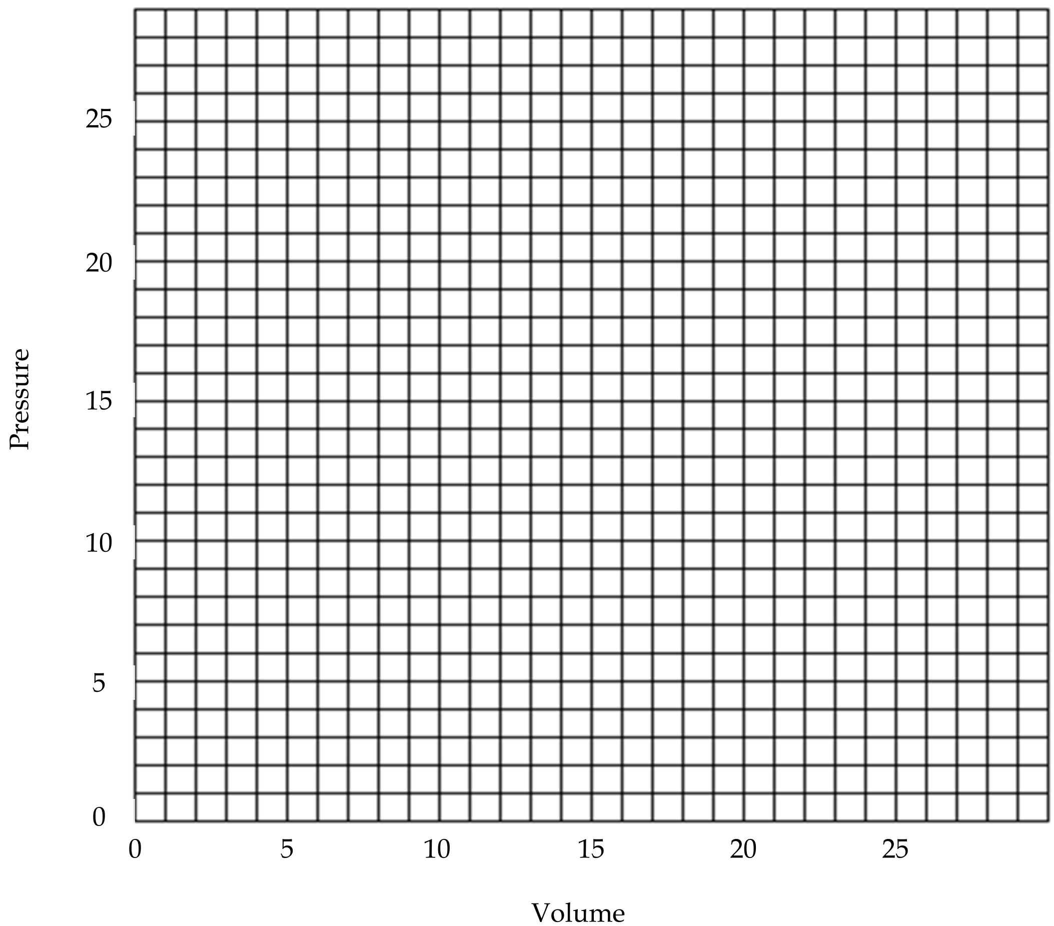
Collect five data points

For each run:

- Change the pressure by moving the pin to different positions.
- Wait for the piston to settle down.
- Press the **Show Average Values** button. When the average values become stable, record the average pressure and the average volume in the following table.

	Volume	Pressure
1		
2		
3		
4		
5		

Graph pressure vs. volume

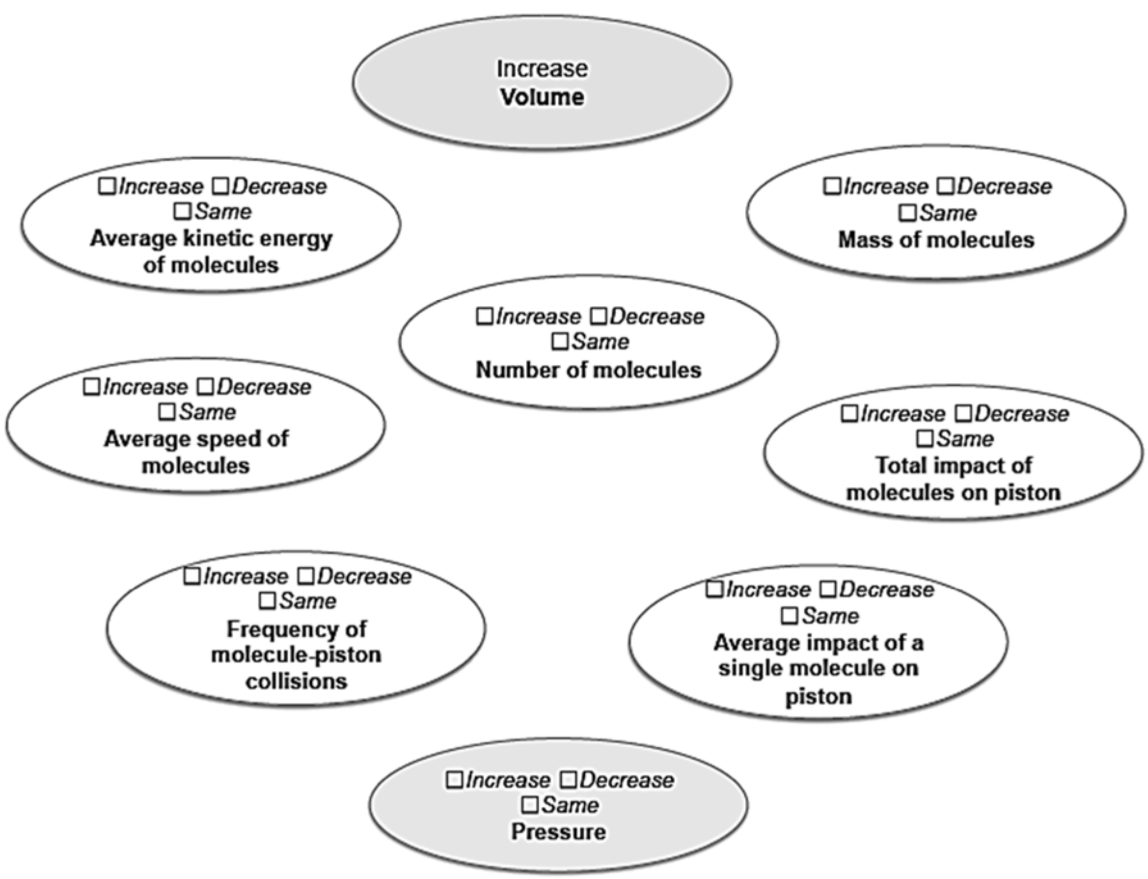


Molecular explanation

Run the model again. Slowly increase the volume from 10 to 20 and observe the movement of molecules. Make sure that **the number of molecules is around 100** in both cases. Pay attention to the differences in **the speeds of molecules**, **the impact of molecules on the piston**, and **the frequency of collisions of molecules with the piston**.

Based on your observation, **link the bubbles with arrows** to explain why increasing the volume of the gas changes its pressure. For each linked bubble, mark the correct box to indicate whether the corresponding property will increase, decrease, or remain the same. You can have more than one arrow coming out of or pointing to a bubble if necessary.

Use the arrows to show a chain of cause and effect



Investigation 5: Explore the relationship between temperature and pressure of gas in the same volume

In this experiment, you will change the temperature by touching the sensor tip with objects of different temperatures. Try to **keep the volume constant**.

Start the model and record the volume and number of molecules (**don't use fewer than 50 molecules**), which will remain constant throughout the experiment:

Volume: ________________ Number of Molecules: ______________

Collect four data points

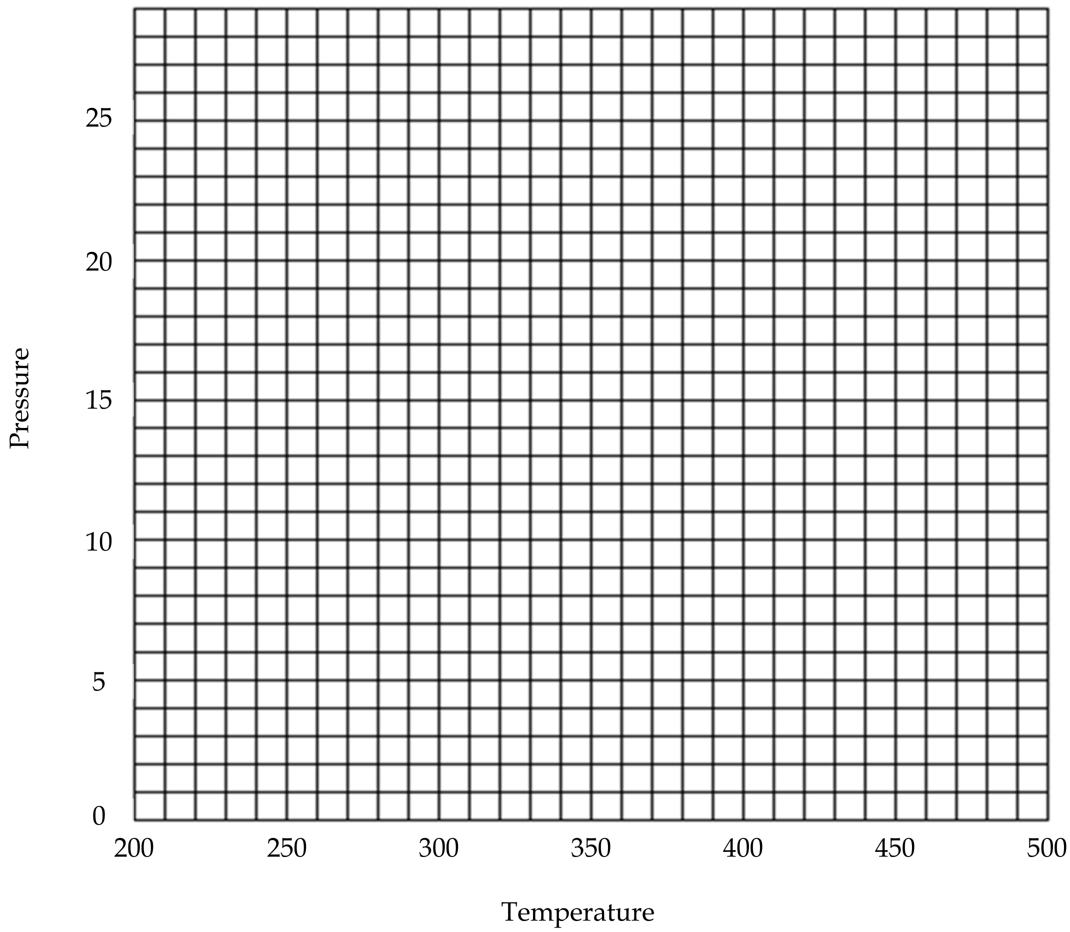
For each run:

- Change the temperature by touching objects of different temperatures to the tip of the temperature sensor.
- Wait for the temperature to settle down (this may take a while).
- Push or pull on the spring to bring the volume to the original value. **Don't expect perfection! It's OK if the volume is within 0.5 of the original.** Wait a few seconds for the piston to settle down.
- Press the **Show Average Values** button. When the average values become stable, record the temperature and pressure in the following table.

	Temperature*	Pressure
Room temperature		
Ice water		
Finger**		
Hot water		

* The temperature is exaggerated for you to see differences more easily.
** You can rub your hands to increase the temperature of your fingers if they are too cold.

Graph pressure vs. temperature

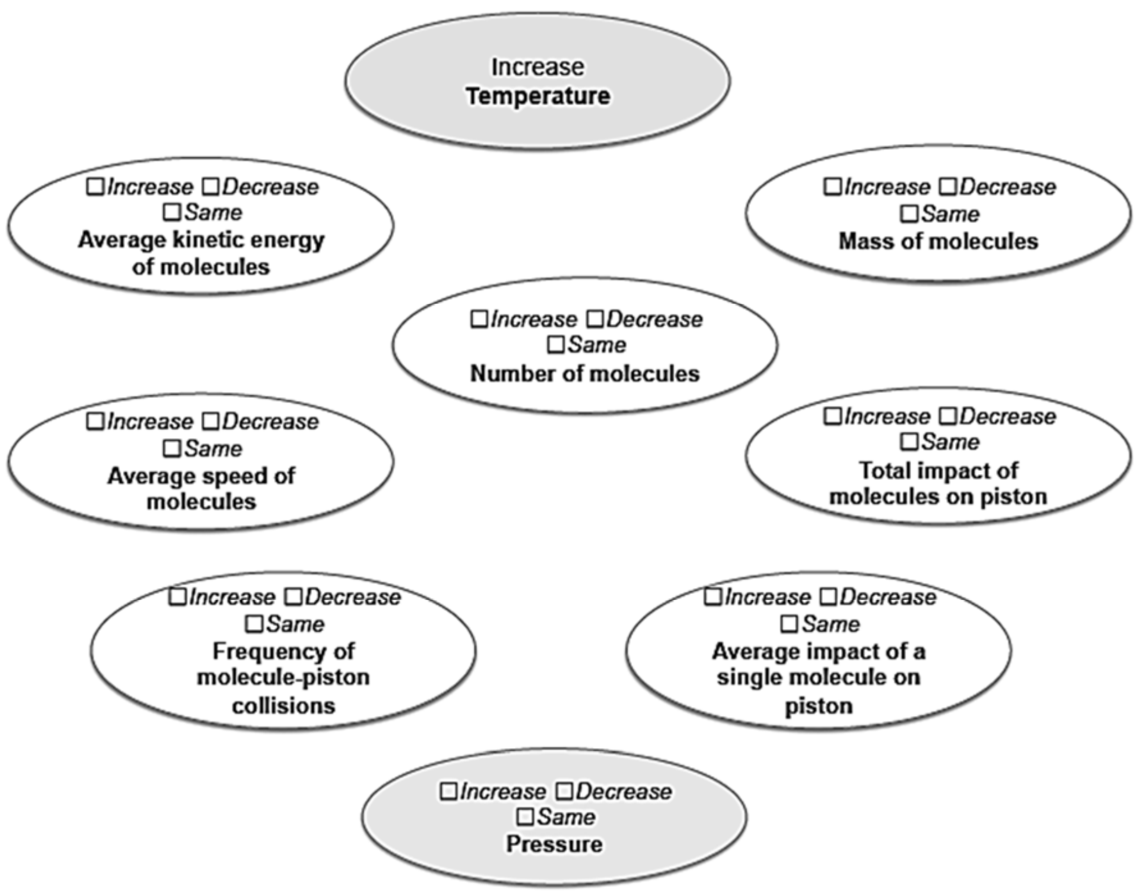


Molecular explanation

Run the model again. Heat the molecules with a hot water jar and observe the change of molecule movement. Pay attention to the differences in **the speeds of molecules**, **the impact of molecules on the piston**, and **the frequency of collisions of molecules with the piston**.

Based on your observation, **link the bubbles with arrows** to explain why increasing the temperature of gas changes its pressure. For each linked bubble, mark the correct box to indicate whether the corresponding property will increase, decrease, or remain the same. You can have more than one arrow coming out of or pointing to a bubble if necessary.

Use the arrows to show a chain of cause and effect



(Optional) Investigation 6: Explore the effect of molecular mass

In this experiment, you will evaluate the effect of mass of molecules on gas volume. You can use the plunger to add or remove type A or B molecules. **The mass of a type B molecule is four times of that of a type A molecule**. While you are experimenting with different types of molecules, **keep the temperature and pressure constant**.

Start the model and record the temperature and pressure, which will remain constant throughout the experiment:

Temperature: ________________ Pressure: __________________

Collect five data points

Put in type A and type B molecules as instructed in the following table and record the volume in each case. Note: Remove all the molecules first and then gradually add type A or B molecules. It may be hard to get exact proportions and numbers; close is good enough.

	Volume
100 type A molecules	
100 type B molecules	
A mixture of 100 molecules with about 25% type A	
A mixture of 100 molecules with about 50% type A	
A mixture of 100 molecules with about 75% type A	

Observe the movement of the two types of molecules.

a. Compare their average speeds.

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b. Compare their impact on the piston.

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c. Compare their frequency of collisions with the piston.

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Molecular explanation

What can you conclude from your data about the effect of changing molecular mass on the volume? Explain your results using molecular concepts.