Gas Variables

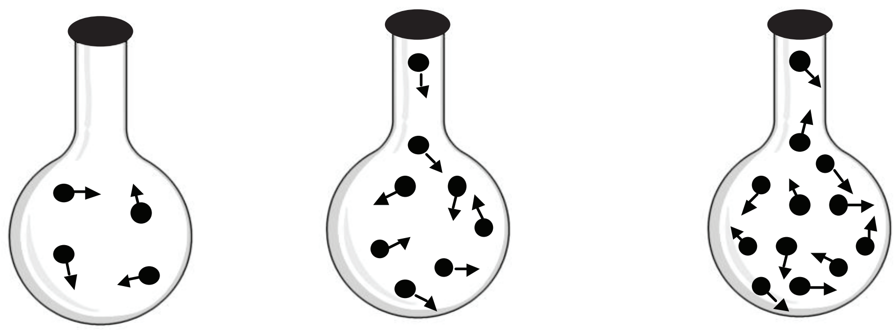
How are the variables that describe a gas related?

Why?

Imagine buying a balloon bouquet at a party store. How will the helium gas in the bouquet behave if you carry it outside on a hot summer day? How will it behave if you carry it outside during a snowstorm? What happens if the balloons are made of latex, which can stretch? What happens if the balloons are made of Mylar®, which cannot stretch? What if you add just a small amount of gas to each balloon? What if you add a lot of gas? In this activity, you will explore four variables that quantify gases—pressure (P), volume (V), temperature (T), and moles (n) of gas. These four variables can be related mathematically so that predictions about gas behavior can be made.

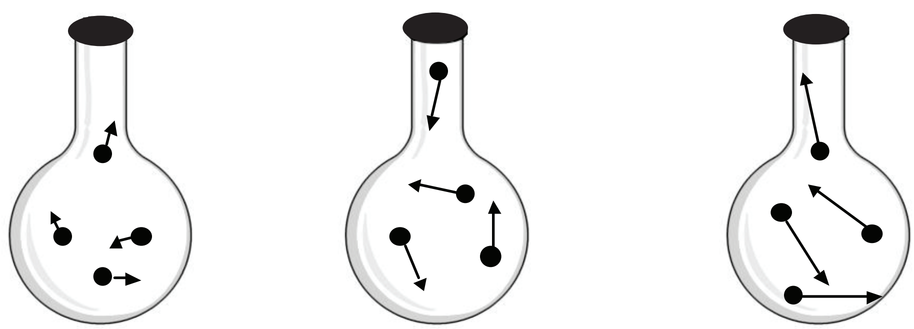
Model 1 – Gases in a Nonflexible Container

Experiment A (Adding more 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 = 200 K	Temperature = 200 K

Experiment B (Heating the gas)



B1	B2	B3
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

**Note:* Volume in this model is recorded in *units* rather than liters because 4 molecules of gas at the conditions given would occupy a very small space ($\sim 1 \times 10^{-22}$ μL). The particles shown here are much larger compared to the space between them than actual gas particles.

1. In Model 1, what does a dot represent?

2. Name two materials that the containers in Model 1 could be made from that would ensure that they were "nonflexible?"

3. In Model 1, the length of the arrows represents the average kinetic energy of the molecules in that sample. Which gas variable ($P_{internal}$, V, T or n) is most closely related to the length of the arrows in Model 1?

4. Complete the following table for the two experiments in Model 1.

	Experiment A	**Experiment B**
Independent Variable		
Dependent Variable		
Controlled Variable(s)		

5. Of the variables that were controlled in both Experiment A and Experiment B in Model 1, one requires a nonflexible container. Name this variable, and explain why a nonflexible container is necessary. In your answer, consider the external and internal pressure data given in Model 1.

Read This!

Pressure is caused by molecules hitting the sides of a container or other objects. The pressure changes when the molecules change *how often* or *how hard* they hit. A nonflexible container is needed if the gas sample is going to have an internal pressure that is different from the external pressure. If a flexible container is used, the internal pressure and external pressure will always be the same because they are both pushing on the sides of the container equally. If either the internal or external pressure changes, the flexible container walls will adjust in size until the pressures are equal again.

6. Name the two factors related to molecular movement that influence the pressure of a gas.

7. Provide a molecular-level explanation for the increase in pressure observed among the flasks of Experiment A.

8. Provide a molecular-level explanation for the increase in pressure observed among the flasks of Experiment B.

9. Predict what would happen to the volume and internal pressure in Experiment A of Model 1 if a flexible container were used.

10. Predict what would happen to the volume and internal pressure in Experiment B of Model 1 if a flexible container were used.

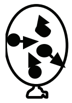
11. For each experiment in Model 1, determine the relationship between the independent and dependent variables, and write an algebraic expression for the relationship using variables that relate to the experiment ($P_{internal}$, V, T or n). Use *k* as a proportionality constant in each equation.

	Experiment A	**Experiment B**
Direct or Inverse Proportion?		
Algebraic Expression		

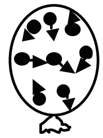
STOP

Model 2 – Gases in a Flexible Container

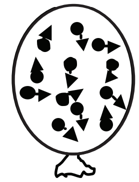
Experiment C
(Adding more gas)



C1
Volume = 1 unit
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 200 K

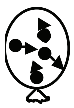


C2
Volume = 2 units
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 200 K

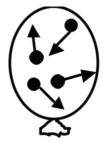


C3
Volume = 3 units
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 200 K

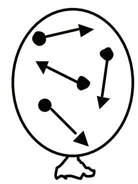
Experiment D
(Heating the gas)



D1
Volume = 1 unit
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 200 K

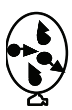


D2
Volume = 2 units
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 400 K

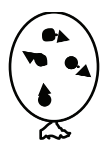


D3
Volume = 3 units
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 600 K

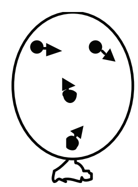
Experiment E
(Reducing the external pressure on the gas)



E1
Volume = 1 unit
External pressure = 1 atm
Internal pressure = 1 atm
Temperature = 200 K



E2
Volume = 2 units
External pressure = 0.50 atm
Internal pressure = 0.50 atm
Temperature = 200 K



E3
Volume = 3 units
External pressure = 0.33 atm
Internal pressure = 0.33 atm
Temperature = 200 K

12. Consider the gas samples in Model 2.

    a. Name two materials that the containers in Model 2 could be made from that would ensure that they were “flexible”?

    b. What is always true for the external and internal pressures of a gas in a flexible container?

13. Complete the following table for the three experiments in Model 2.

	Experiment C	**Experiment D**	**Experiment E**
Independent Variable			
Dependent Variable			
Controlled Variable(s)			

14. Provide a molecular level explanation for the increase in volume among the balloons in Experiment C. (How often and/or how hard are the molecules hitting the sides of the container?)

15. Provide a molecular level explanation for the increase in volume among the balloons in Experiment D.

16. Provide a molecular level explanation for the increase in volume among the balloons in Experiment E.

STOP

17. Compare Experiment A of Model 1 with Experiment C of Model 2. How are these two experiments similar and how are they different in terms of variables?

18. Compare Experiment B of Model 1 with Experiment D of Model 2. How are these two experiments similar and how are they different in terms of variables?

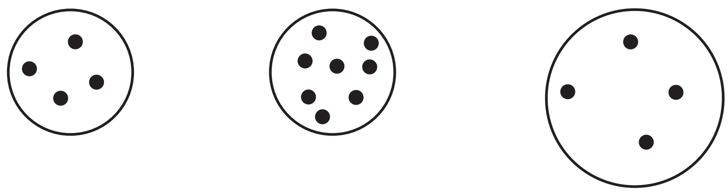
19. If Experiment E of Model 2 were done in a nonflexible container, would there be any change to the internal pressure of the flask when the external pressure was reduced? Explain.

20. For each experiment in Model 2, determine the relationship between the independent and dependent variables, and write an algebraic expression for the relationship using variables that relate to those in the experiment ($P_{internal}$, V, T or n). Use *k* as a proportionality constant in each equation.

Constant Pressure

	Experiment C	**Experiment D**	**Experiment E**
Direct or Inverse Proportion?			
Algebraic Expression			

21. The three samples of identical gas molecules below all have the same internal pressure. Rank the samples from lowest temperature to highest temperature, and add arrows of appropriate size to illustrate the average kinetic energy of the molecules in the samples.



Extension Questions

22. Draw a sample of gas that is colder than all three of the samples in Question 21. Explain why you are sure that it is colder.

23. Four of the relationships you investigated in Models 1 and 2 are named after scientists who discovered the relationships. Use the Internet or your textbook to match each of the scientists below with the appropriate law. Write the algebraic expression that describes the law in the box below each name.

Robert Boyle	Jacques Charles	Guillaume Amontons	Amedeo Avogadro

Read This!

Chemists combine all of the relationships seen in Models 1 and 2 into one law—the **Ideal Gas Law**. It is one equation that describes gas behavior and the relationship among all four variables, P, V, T, and n. In the Ideal Gas Law the proportionality constant is represented by the letter R (rather than the generic *k*).

24. Circle the algebraic equation below that best combines all of the relationships you identified among P, V, T, and n in this activity.

    $P = RTnV$ $PT = RnV$ $PV = nRT$ $PTV = Rn$