Name _____ Date _____ Period _____

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Gas Laws and KMT Virtual Lab

Chemistry and AP Chemistry

Open **activities.zornscience.org/gas-lab/** and follow each step. To type a value, click the number box, type, and press Enter. Show your work with units.

Objective

Use a particle model of a gas to find how **pressure**, **volume** and **temperature** are related, and how kelvin temperature is connected to particle **kinetic energy** and **speed**.

NGSS alignment: HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).
Practices and concepts: Developing and using models; Analyzing and interpreting data; Using mathematics; Scale, proportion, and quantity; Cause and effect.
AP alignment: 3.4 Ideal Gas Law; 3.5 Kinetic Molecular Theory; 3.6 Deviation from Ideal Gas Law. Skills 5.C, 4.A and 6.E.

Meet the simulation

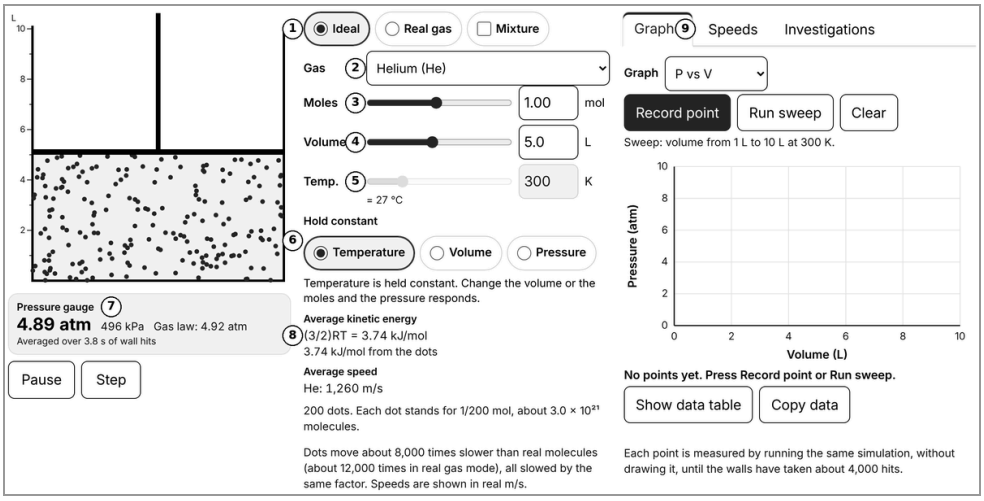


Figure 1. The Gas Laws and KMT Lab.

1. Model: Ideal, Real gas or Mixture.
2. Gas menu.
3. Moles (each dot is 1/200 mol).
4. Volume (moves the piston).
5. Temperature in K.
6. Hold constant. The held control turns gray.
7. Pressure gauge. "Gas law" is the PV = nRT value.
8. Average kinetic energy and speed.
9. Tabs, including Speeds.

Pre-lab

1. According to kinetic molecular theory, what causes the pressure of a gas? What happens to the pressure if the particles hit the walls more often?

2. Use PV = nRT (R = 0.08206 L·atm/(mol·K)) to calculate the pressure of 2.00 mol of gas at 400 K in 8.00 L.

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Part A. Pressure and volume

1. Select **Ideal**, gas **Helium (He)**, **1.00** mol, **300** K. Hold constant: **Temperature**.
2. Type each volume below. Wait about 5 s for the gauge to settle, then record the gauge and the **Gas law** value.

Volume (L)	Gauge pressure (atm)	Gas law pressure (atm)	P × V (atm·L)
10.0			
5.0			
2.5			

3. What happens to the pressure when the volume is cut in half? What stays the same in the last column? Name this gas law and write its equation.

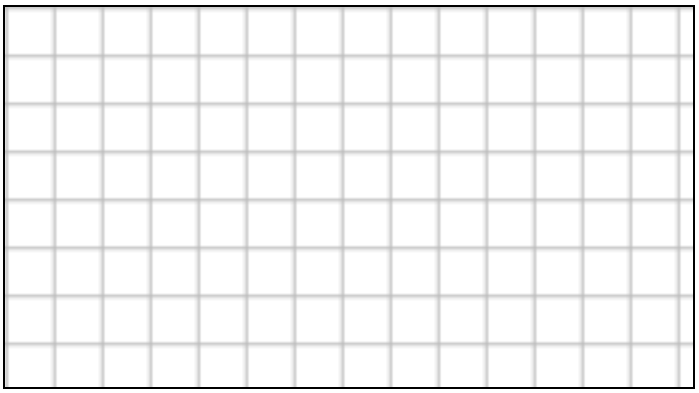
4. Watch the dots as you change from 10.0 L to 2.5 L. The temperature (and particle speed) did not change. Explain with particles why the pressure went up.

Part B. Temperature, energy and speed

1. Keep He, **1.00** mol. Type a volume of **5.0** L, then select Hold constant: **Volume**.
2. Type each temperature below and record the Gas law pressure, (3/2)RT and the average speed.

Temperature (K)	Temperature (°C)	Gas law pressure (atm)	Average kinetic energy (3/2)RT (kJ/mol)	Average speed of He (m/s)
150				
300				
600				
900				

5. Graph pressure (y-axis) against kelvin temperature (x-axis). Label both axes with units and draw a line of best fit. Where does the line meet the x-axis?



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6. When the kelvin temperature doubled from 300 K to 600 K, by what factor did the average kinetic energy change? The average speed? Show the speed ratio with numbers.

7. A student says, "Heating from 27 °C to 327 °C makes the particles 12 times more energetic." Use your table to correct the student.

Part C. Different gases at the same temperature

1. Keep **1.00** mol, **300** K, **5.0** L. Choose each gas below from the Gas menu and record the readouts.
2. Open the **Speeds** tab and select **He vs Ar** (Figure 2).

Gas	Molar mass (g/mol)	(3/2)RT (kJ/mol)	Gas law P (atm)	Average speed (m/s)
He	4.00			
N_2	28.01			
Ar	39.95			
Xe	131.29			

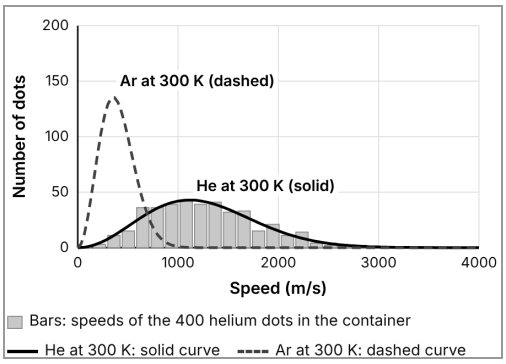


Figure 2. Speed curves for He and Ar at 300 K (Speeds tab).

8. Which readouts were the same for every gas? Which changed? Explain why heavier particles move more slowly at the same temperature.

9. In Figure 2, describe two ways the argon curve differs from the helium curve. Use particle mass to explain the difference.

10. (AP extension) Show that the ratio of average speeds of He and Xe equals $\sqrt{(M_{Xe}/M_{He})}$.

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Part D. (AP extension) Real gases

1. Check that the temperature is **300** K. Select **Real gas**, choose **Carbon dioxide (CO_2)**, type **1.00** mol, and select Hold constant: **Temperature**.
2. Type each volume and record the van der Waals pressure, the ideal gas law pressure and PV/nRT. Then repeat with **Helium (He)**.

Gas	Volume (L)	Real pressure (atm)	Ideal gas law (atm)	PV/nRT
CO_2	2.50			
CO_2	1.00			
CO_2	0.50			
He	2.50			
He	0.50			

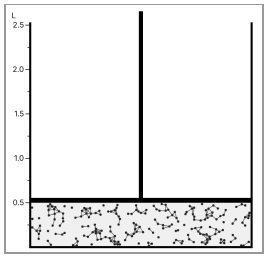


Figure 3. CO_2 at 0.50 L. Lines join dots close enough to attract.

11. (AP extension) For CO_2, how does PV/nRT change as the gas is squeezed? Is the real pressure higher or lower than ideal? Explain using attractions between particles.

12. (AP extension) Helium's PV/nRT is above 1 at 0.50 L. What causes this, and why does helium behave so differently from CO_2?

Analysis

13. In Part A the gauge readings were close to, but not exactly equal to, the Gas law values. Explain why. Then give one way a real gas law lab would differ from the ideal simulation.

Conclusion

14. Write a claim that answers the objective. Support it with evidence from Parts A, B and C (specific numbers), then explain your reasoning with kinetic molecular theory.

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