Gas Properties Simulation Activity

In this activity you’ll use the Gas Properties PhET Simulation (https://phet.colorado.edu/en/simulation/gas-properties) to explore and explain the relationships between energy, pressure, volume, temperature, particle mass, number, and speed.

This activity has 5 modules:
- Explore the Simulation
- Kinetic Energy and Speed
- Kinetic Molecular Theory of Gases
- Relationships between Gas Variables
- Pressure and Mixtures of Gases

You will get the most out of the activity if you do the exploration first! The rest of the sections can be worked in any order; you could work on any sections where you want to deepen your conceptual understanding.

Part I: Explore the Simulation

Take about five minutes to explore the sim. Note at least two relationships that you observe and find interesting.
Part II: Kinetic Energy and Speed

Sketch and compare the distributions for kinetic energy and speed at two different temperatures in the table below. Record your temperatures (T₁ and T₂), set Volume as a Constant Parameter, and use roughly the same number of particles for each experiment (aim for ~100-200). Use the T₂ temperature to examine a mixture of particles.

**Tips:**

- The Species Information and Energy Histograms tools will help.
- The system is dynamic so the distributions will fluctuate.
- Sketch the average or most common distribution that you see.

<table>
<thead>
<tr>
<th></th>
<th>“Heavy” Particles Only</th>
<th>“Light” Particles Only</th>
<th>Heavy + Light Mixture</th>
</tr>
</thead>
<tbody>
<tr>
<td># of particles (~100-200)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinetic Energy Distribution sketch for T₁</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Distribution sketch for T₁</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kinetic Energy Distribution sketch for T₂</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed Distribution sketch for T₂</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

T₁ = __________K  
T₂ = __________K
1. Compare the kinetic energy distributions for the heavy vs. light particles at the same temperature. Are these the same or different? What about the speed distributions?

2. Compare the kinetic energy distributions for the heavy vs. light particles at different temperatures. Are these the same or different? What about the speed distributions?

3. Compare the kinetic energy distributions for the mixture to those of the heavy-only and light-only gases at the same temperature. Are these the same or different? What about the speed distributions?

4. Summarize your observations about the relationships between molecular mass (heavy vs. light), kinetic energy, particle speed, and temperature.
**Part III: Kinetic Molecular Theory (KMT) of Gases**

Our fundamental understanding of “ideal” gases makes the following 4 assumptions. Describe how each of these assumptions is (or is not!) represented in the simulation.

<table>
<thead>
<tr>
<th>Assumption of KMT</th>
<th>Representation in Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Gas particles are separated by relatively large distances.</td>
<td></td>
</tr>
<tr>
<td>2. Gas molecules are constantly in random motion and undergo elastic collisions (like billiard balls) with each other and the walls of the container.</td>
<td></td>
</tr>
<tr>
<td>3. Gas molecules are not attracted or repulsed by each other.</td>
<td></td>
</tr>
<tr>
<td>4. The average kinetic energy of gas molecules in a sample is proportional to temperature (in K).</td>
<td></td>
</tr>
</tbody>
</table>
Part IV: Relationships Between Gas Variables

Scientists in the late 1800’s noted relationships between many of the state variables related to gases (pressure, volume, temperature), and the number of gas particles in the sample being studied. They knew that it was easier to study relationships if they varied only two parameters at a time and “fixed” (held constant) the others. Use the simulation to explore these relationships.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Constant Parameters</th>
<th>Relationship</th>
<th>Proportionality (see hint below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pressure, volume</td>
<td></td>
<td></td>
<td>directly proportional or inversely proportional</td>
</tr>
<tr>
<td>volume, temperature</td>
<td></td>
<td></td>
<td>directly proportional or inversely proportional</td>
</tr>
<tr>
<td>volume, number of gas particles</td>
<td></td>
<td></td>
<td>directly proportional or inversely proportional</td>
</tr>
</tbody>
</table>

Hint: A pair of variables is *directly proportional* when they vary in the same way (one increases and the other also increases). A pair of variables is *inversely proportional* when they vary in opposite ways (one increases and the other decreases). Label each of your relationships in the table above as directly or inversely proportional.
Part V: Pressure and Mixtures of Gases

The atmosphere is composed of many gases in different ratios, and all of them contribute to the total atmospheric pressure. Use the simulation to explore this relationship by testing combinations of heavy and light gases.

For each Test #, record your measurement and make the prediction before moving on to the next row of the table.

<table>
<thead>
<tr>
<th>Test #</th>
<th>Pressure Measurement</th>
<th>Pressure Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100 Light particles =</td>
<td>Pressure for 100 Heavy Particles will be ______________ the pressure from Test #1.</td>
</tr>
<tr>
<td>2</td>
<td>100 Heavy particles =</td>
<td>Pressure for 200 Heavy particles will be ______________ the pressure from Test #2.</td>
</tr>
<tr>
<td>3</td>
<td>200 Heavy particles =</td>
<td>Pressure for 100 Light AND 100 Heavy particles will be ______________ the pressure from Test #3</td>
</tr>
<tr>
<td>4</td>
<td>100 Heavy + 100 Light particles =</td>
<td>Pressure for 200 Heavy AND 100 Light particles will be ______________ the pressure from Test #4.</td>
</tr>
<tr>
<td>5</td>
<td>200 Heavy + 100 Light particles =</td>
<td>Pressure for 150 Heavy AND 50 Light particles will be ______________ the pressure from Test #5.</td>
</tr>
<tr>
<td>6</td>
<td>150 Heavy + 50 Light particles =</td>
<td>Write your own prediction:</td>
</tr>
</tbody>
</table>
1. For Test 6 (150 Heavy + 50 Light particles), what is the pressure contribution from the heavy particles ($P_{\text{heavy}}$)? How did you figure this out?

2. What is the pressure contribution from the light particles ($P_{\text{light}}$)? How did you figure this out?

3. For each test above, calculate the mole fraction of each gas (number of particles of that type / total particles). Find a relationship between the mole fraction and the pressure contribution of each type of gas.

4. The atmosphere is composed of about 78% nitrogen, 21% oxygen, and 1% argon. Typical atmospheric pressure in Boulder, Colorado is about 0.83 atm. What is the pressure contributed by each gas?