Lesson plan for *Gas Properties* Chemistry: Gas Laws

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Learning Goals:

- Design experiments to measure the relationships between pressure, volume, and temperature.
- Create graphs based on predictions and observations.
- Make qualitative statements about the relationships between pressure, volume and temperature using molecular models.

Background:

Honors Chemistry: My students for the most part have had physics where we used this simulation for Kinetic Molecular Theory and some for Buoyancy and Pressure. A few days before this activity, we used States of Matter Basics activity. We will use this for an introduction to Gas Laws and then do a lab where they use Alka-Seltzer and water in balloons to get a gross understanding of stoichiometric application of gas laws; the lab does not give very quantitative data and doing many variations is expensive, so we use the lab just for a qualitative application. This activity was designed to push towards quantitative relationships and serve as an introduction before lecturing on the Gas Laws.

Regular Chemistry: My students have not had physics, but States of Matter and molecular representations have been a thread in the course. This activity does assume previous knowledge: Students are able to describe a molecular model of gas pressure. This is well described in my book and they did States of Matter Basics activity early in the year.

***Gas Properties* Introduction:**

I did not demonstrate the sim, but I reminded students that they need at least 6 points to get a trend and that using zero is never a good idea. The hint I put in the directions is important; if students set a parameter to be constant, they can make a change, but must wait for the parameter to return to the set value.

Lesson: My students did this in class in pairs, but it is suitable for homework after students have done at least the first 2 experiments or have good experimental design and analysis skills. My students used the idea that measuring the width (the Ruler is under Measurement Tools) of the container could be used to find the trends for volume because they assumed that height and depth would not vary. This worked well and the trend lines demonstrated the laws well. For example, they used volume as the independent variable and pressure as the dependent variable. Students started the experiment with no constants selected, put in some particles, let the pressure come to a constant and then check "constant Temperature". If they use the little guy to change the volume some and then let the temperature return to 300, the plot of PV gave a power trend with an exponent of -1 as expected and those students who were careful also had nearly 1 for r-squared.

I told the students that they would need to use their books or the web to answer some of the questions.

The Tips for Teachers written by the PhET team for this sim could be useful. For example, this sim would not be useful for determining constants since the volume is not truly represented.

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Reflection comments from my experience with this activity: I used this lab in a regular chemistry course where the students have not had much quantitative design experience although they do many inquiry labs where they are looking for general trends. The students who had poor r-squared values often had a very small range for width, very few particles, did not wait for the temperature to equilibrate, or changed the volume so dramatically that PV work affected their results. Many students had forgotten how to evaluate good lab practice and struggled with deciding which variable to be independent and also how to manipulate the sim to properly hold other variables constant. My students commented that it really made them think about experimental design and they also were glad to use Excel because many had forgotten how to properly fit trend lines and use r-squared to help them.

Post Lesson: I used some clicker questions. Then we used the book to formally see the Laws. I emphasized that quotients indicate direct relationships and products indicate indirect relationships.