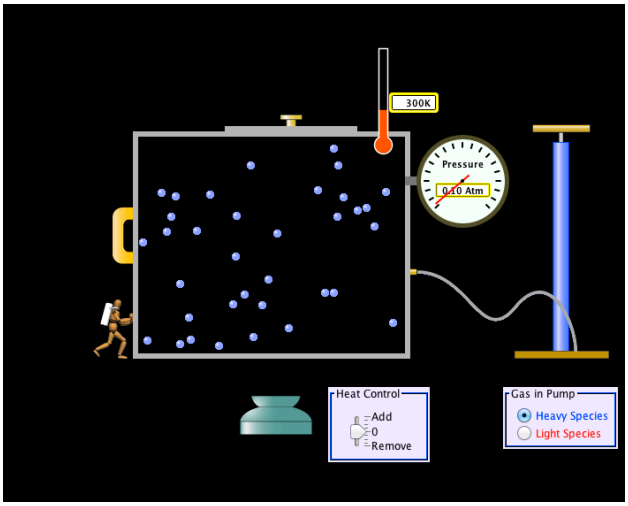
Kinetic Theory of Gases and the Ideal Gas Law

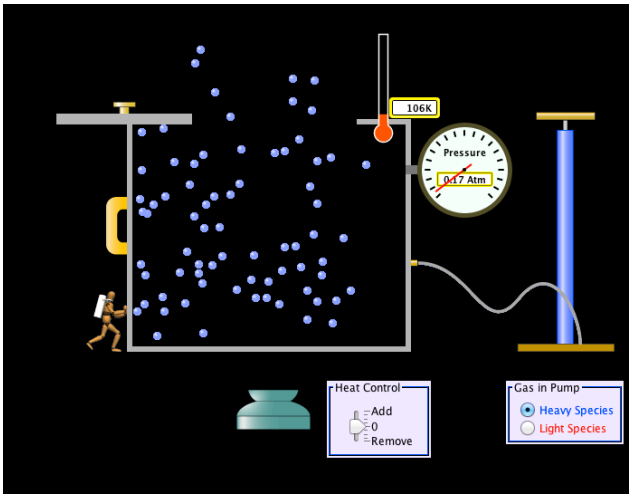
Start the PhET simulation, *Gas Properties* and leave the container empty. This is a good opportunity to use an interactive whiteboard, if available.



Write the ideal gas law on the board for reference and introduce the idea of explaining the **macroscopic** features of the gas with reference to **microscopic** properties.

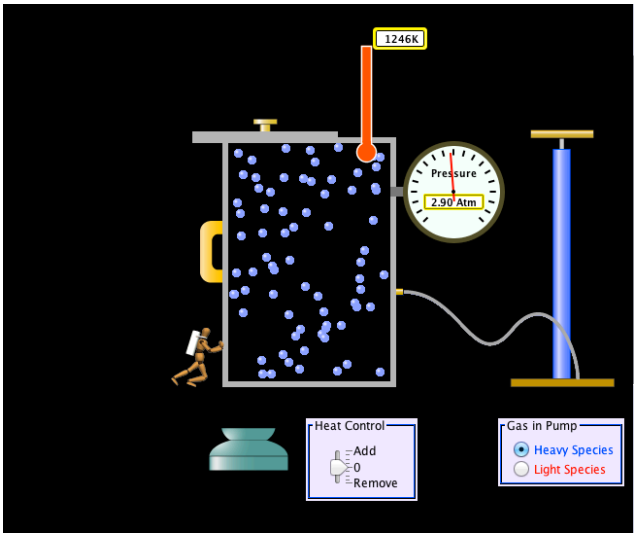
Start with ***n*** in the gas law:

- What is the microscopic object related to this parameter? How can I introduce it into the box in the simulation?
- Notice that the ideal gas law has a version for dealing with number of molecules (N) rather than moles (n). What is k_B in this version of the equation? What kind of magnitude is k_B compared to R in the macro version of the equation. Does this difference make sense?
- Predict what will happen when the cover is opened for a time and jot down your answer.
- Did you correctly predict that <u>both</u> pressure and temperature would change when N was decreased? This illustrates that the variables in the ideal gas law are **codependent**; changing one value does not usually mean only one of the other values changes. We will come back to explain these other changes from the microscopic viewpoint.



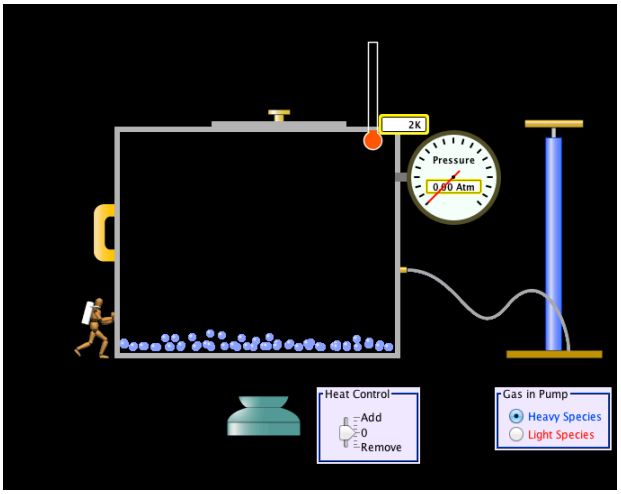
Now consider ***V*** in the gas law:

- How can we control this in the simulation? What can you say about most of the volume in the box when considered from the microscopic viewpoint?
- Predict what happens to the other parameters if the volume is reduced by half. Jot down your prediction of all the changes that will occur.
- Did you predict that both pressure and temperature would be increased? This again shows that these are not simple relations, but complex. Again, we will come back to this.
- How did N change? Notice that half the volume doesn't mean *half the gas*, but *half the space*.



Let's now turn our attention to ***T***:

- How might we increase the temperature of the gas? What is the microscopic effect of increasing the temperature of the gas? [Students will respond with **speed**, however the more accurate relation is **kinetic energy**. Explain.]
- Is the kinetic energy of every particle the same? If particles move with different kinetic energies, what do we mean when we say that higher temperature means higher kinetic energy?
- What would the particles look like with nearly zero kinetic energy? [Add a little gravity, then remove energy from the gas.] Did you predict that the gas would liquefy?



[Reset the simulation to normal temperature before demonstrating each situation below.]

Let's see how this microscopic view helps us explain some of our previous observations.

- What happed to the *temperature* in the first simulation when the lid was opened for a short time? How can we explain this temperature drop considering only the kinetic energy of the gas particles? (Hint: which particles are most likely to leave the container?)

- What happened to the *temperature* in the second simulation when volume was decreased? How can we explain this temperature increase considering only the kinetic energy of the gas particles? (Hint: As the side of the container is pushed in, what does it do to the particles it hits?)

- Notice that in both cases, our microscopic viewpoint has allowed us to explain interactions that we might not have predicted from the ideal gas law alone.

Let's see if we can explain ***P*** in terms of microscopic interactions as well:

- Carefully watch the moveable wall of the container. Why does the man struggle to hold it in place? Use only a microscopic features in your explanation.

- You should have noticed that particle collisions with the wall are the microscopic basis for pressure. *Thinking only about the collisions*, what could we change the about the gas to change the pressure (or the force the man has to apply to the wall)?
    - Frequency of collisions?
    - Speed of collisions? (momentum change of collision)
- What can we change in the simulation to demonstrate each of these microscopic changes? Did our changes also change the pressure?

  [Instructor note: Along with other factors N and V, T (and kinetic energy) will affect <u>both</u> the frequency and momentum change of collisions.]

Let's see if this microscopic view of pressure helps explain our previous observations.

- What happed to the *pressure* in the first simulation when the lid was opened for a short time? How can we explain this pressure drop considering only the magnitude and number of collisions of the gas particles with the wall?

- What happened to the *pressure* in the second simulation when volume was decreased? How can we explain this pressure increase considering only the collisions of the gas particles with the wall?