Gas Properties Activity Using Phet Simulation

Name:
Group Members:

Web site for simulations:
http://phet.colorado.edu/en/simulation/gas-properties

**Note: You must have JAVA loaded on computer for simulation to work.**
You can find a link to the JAVA download on the “downloads” page of the site above.

We recommend reading the entire question and then strategizing how best to answer the question. This is not a step-by-step activity. Make sure to answer the why parts!

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Part I.
**Goals: difference between ideal and real gases**
**Applying the volume correction to the ideal gas law**

1. Place 1 and 100 heavy particles in the box with interactions (molecules collide) turned off. Deduce the following for each case: How do the mean speed and temperature vary with time? How does pressure vary with time? Why?
   For n=1, the mean speed and T don’t vary, and the P = 0 atm
   For n=100, the mean speed and T don’t vary, as well as, the P varies slightly.
   Since the molecules do not interact with each other, their momentum is constant.
   Therefore, the mean velocity and T don’t change.
   The P doesn’t vary because the F/A is pretty constant at every Δt, since velocity is constant.

2. Place 1 and 100 heavy particles in the box with interactions (molecules collide) turned on. Deduce the following for each case: How do the mean speed and temperature vary with time? How does pressure vary with time? Why?
   For n=1, the mean velocity and T don’t change, and the P = 0 atm
   For n=100, the mean velocity varies around an average value, the T is constant, and the P varies.
   The mean velocity will change with collisions (elastic collisions) but will change around a constant value because the system is at equilibrium. The T is constant since the mean velocity doesn’t deviate far from a constant velocity value.
   The P varies because the F/A is not constant over time. The velocity has a distribution and therefore each collision with the wall is slightly different.

3. From earlier today, we derived PV=nRT. What are the assumptions that make the ideal gas law work? Which of these assumptions will no longer hold true when we turn the interactions function on? What terms within the ideal gas law will be affected by the interactions turned on?
Assumptions to the ideal gas law
1. Molecules are volumeless
2. No attractive forces between molecules
   No longer true: molecules are colliding and have a finite volume
   The volume term will be different (smaller) which will in turn increase the pressure (as long as T and n are kept constant).

4. Place 100 particles in the box with a temperature near room temperature and randomized trajectories. With the interactions off record the pressure, the mean speed and the temperature. Turn on the interactions and record the same properties. What happened? Why? Do this with 500, 200, 50, and 10 particles in the box. Suggest the form for an appropriate equation of state for the gas when the particle – particle interaction is turned on. The van der Waals equation of state is a good place to begin to think about this problem. Consider how the VdW equation of state corrects for non-ideality.
   The pressure consistently went up as the interactions were turned off. The speed and T stayed roughly the same. This occurred because as the molecules collide they are no longer volumeless (as the ideal gas law says they are). There must be some correction for volume of the particles
   In VdW:
   \[ P = \frac{nRT}{V-nb} - \frac{a n^2}{V^2} \]
   Need to correct the volume term. The molecules have less space to roam if they cannot go through other molecules. Need to reduce the volume term
   So will you use the \( P = \frac{nRT}{V-nb} \) to decrease the amount of volume accessible for roaming

Part II.
Goals: irreversible and reversible processes
1. Place a small number of particles in the box with the interactions turned on and temperature held constant. Move the left wall of the box in and out. First, move the wall fast (this allows the molecules to receive energy from the wall) and second, move the wall slow (this doesn’t allow the molecules to receive energy from the wall). What is the difference in the temperature and velocity in these two circumstances? Do this again with no parameters held constant. What is the difference in the temperature and velocity when you move the wall fast and slow? Which is more comparable to holding T constant, moving the wall fast or slow and why? Can you bring the system back to its initial conditions when you move the wall fast?
   When the T is held constant and the walls are moved slowly and quickly, there is no difference in the gas properties between these two scenarios. But when the T is not held constant and the walls are moved quickly, there is a change in T and velocity. When the T is not held constant and the walls are moved slowly, there is no change in T or velocity. Holding the T constant is like moving the walls slowly: aka there is no transfer of E from wall momentum to particle momentum. Moving the wall slowly is a reversible process; the pressure and velocity can always be brought to their starting value. Moving the wall quickly is an irreversible process; the pressure and velocity cannot be brought back to their starting value.
2. Using the value that you calculated for the average velocity of nitrogen molecules at room temperature, do you think that it is possible that you can move a moveable wall fast enough to transfer significant energy to the molecule? Would this be similar to moving the wall slow or fast? No! you cannot move a wall at a speed comparable to the molecule. You are only able to create the slow wall scenario.

3. In the real world, the speed of the gas particles is much greater than that of a piston, and the direct kinetic energy transfer from the piston to the gas is not significant. Under this very slow motion condition, there is no heat transfer into or out of the gas, and the process is referred to as being adiabatic. The motion of much of our atmosphere is quasi adiabatic, with individual “parcels” of the atmosphere behaving nearly adiabatically. In a Colorado windstorm, parcels of air from the continental divide (p = 0.6 atm) descend rapidly into Boulder (p = 0.8 atm). Assuming that the air on the divide is pretty cold (-20º), what would be the thermal effect of a windstorm in Boulder? Describe what will happen to the “parcels” of air as they descend onto Boulder.

The windstorm will bring warmer weather to Boulder. The parcels will go from a low pressure environment to a high pressure environment and the temperature will increase as it descends into Boulder. There will also be a reduction in the size of the parcel which will further increase the temperature.

Part III.

Goals: higher collision frequency increases diffusion, molecules diffuse faster at lower concentrations, KE is proportional to v²

1. Turn on the center of mass markers. Inject 100 particles with molecule interactions turned off. Allow time for the distribution to appear spatially uniform. At this point, turn on molecular interactions. What happens to the kinetic energy and velocity of the molecules? How are kinetic energy and velocity related?

   Does a-c increase/decrease the kinetic energy and velocity equilibration time? Why?
   a) increase number of particles
   b) increase temperature
   c) decreases mass of the particles

What do a-c have in common in affecting the equilibration time?

The KE and v will not have a distribution until interactions are turned on. KE is proportional to v²

   a) the more particles the faster the system equilibrates. More molecules, higher collision frequency
   b) The higher the T the faster the system equilibrates. Faster molecules, higher collision frequency
   c) lower the mass, faster the molecules move, the faster the system equilibrates.

Faster molecules, higher collision frequency

Summary: higher collision frequency will equilibrate the system faster
2. What is the driving force for speed/kinetic energy equilibration? Hint: why does kinetic energy and speed never equilibrate with the interactions turned off? The collision frequency is the driving force. Without any collisions there cannot be a transfer of energy.

3. Without using the computer simulation, predict what will happen to the equilibration time if the particles were the same mass but twice the radius. Why? The equilibration time would be 4x faster because the there would be a higher collision frequency. Diffusion is propotional to $1/r^2$. 