

Course and Section \_\_\_\_\_

Names \_\_\_\_\_

Date \_\_\_\_\_

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## **IDEAL GAS LAW SIMULATION**

### **Introduction**

This experiment explores the relation between the quantity of pressure  $P$ , volume  $V$ , and temperature  $T$  of an ideal gas of  $N$  number of particles. The ideal gas law is given by,

$$PV = nRT$$

Where  $n$  is number of moles =  $N/(\text{Avogadro number})$  and  $R$  is the gas constant. It can also be shown that

$$nR = Nk_B$$

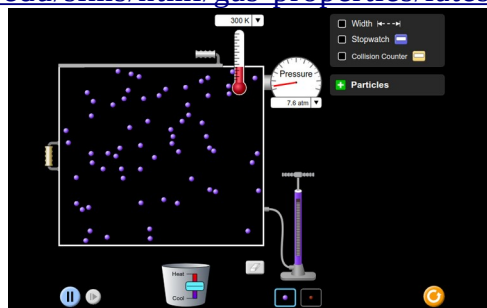
where  $k_B = 1.38 \times 10^{-23}$  J/K is the Boltzmann constant.

Submit your answers using Blackboard.

### **1 – Exploring the Relations Between $P, V, N, T$**

Open the following simulation and select *Explore*

([https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties\\_en.html](https://phet.colorado.edu/sims/html/gas-properties/latest/gas-properties_en.html))



Use the pump to add about 300 blue particles.

1. For a fixed  $N$  and  $V$ , which quantity will increase the pressure if you increase it?
2. For a fixed  $N$  and  $T$ , which quantity will increase the pressure if you decrease it?
3. For a fixed  $V$  and  $T$ , which quantity will increase the pressure if you decrease it?

Display the ‘Collision Counter’ and click on the green play button to start it.

4. If you increase only  $T$ , does the number of collisions increases? (start the counting again).
5. If then you decrease only  $V$ , does the the number of collisions decreases? (start the counting again).

Add some red particles to obtain a mix of blue and red particles.

6. Do the red particles move at the same speed as the blue particles?

7. Are the red particles more massive than the blue particles?

Restart the simulation and decrease the volume to its minimal possible value (use the mouse to drag the handle located on the left of the container). By clicking on Particles, set  $N = 400$  of the blue particles and  $N = 0$  red particles. Check the value of the temperature: it should be 300K, if not start over and repeat.

8. Use the Ideal Gas Law to calculate the minimum volume.

## 2 – Ideal Gas Law

Using the same simulation select *Ideal*. Use the pump to add some particles.

Select *Hold Constant Volume*.

9. What happens to  $P$  if you increase  $T$ ?

10. What happens to  $P$  if you increase  $N$ ?

Start over and click on *Particles* and add 100 heavy (blue) particles. Set the pressure to be constant with variable volume  $\uparrow V$ . Temperature at 300 K. Note the initial volume  $V_i$ . Now add 50 more blue particles so that the volume is now  $V_f$ .

11. What happens to the volume?

12. By using the ideal gas law, what is the ratio of  $V_f / V_i$  ?

Next you want to find the work done by the gas as the number of particles changed from 100 to 150 while  $P$  and  $T$  stay constant. You can display the horizontal width by clicking on 'Width'

13. Which formula gives the work done by a gas when the volume changes at constant pressure?

Assume the cross sectional area (into the page) is  $A = 60 \times 10^{-18} \text{ m}^2$ .

14. Calculate the work done by the gas.

## 3 – Kinetic Theory

Using the same simulation select *Energy*. Select Injection Temperature at 300 K, add some particles until the pressure is about 20 atm. Click to display the Kinetic Energy ( $KE$ ) as well. By looking at the plots

15. The number of particles with low speed is \_\_\_ than the number of particles with high speed.

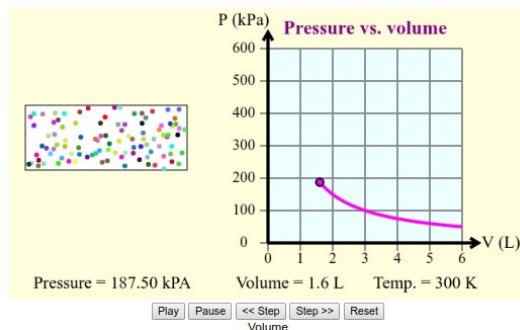
16. The number of particles with low  $KE$  is \_\_\_ than the number of particles with high  $KE$ .

17. If you add more particles to double the pressure, does the average speed increase?

18. If you increase the temperature what happens to the average speed?

## 4 – The *PV* diagram

Open this simulation ([http://physics.bu.edu/~duffy/HTML5/PV\\_diagram.html](http://physics.bu.edu/~duffy/HTML5/PV_diagram.html))



Start by setting the volume = 6 L and Temperature = 600 K.

19. As you decrease the volume how does the pressure change?
20. As you decrease the temperature how does the pressure change?
21. As you increase the temperature how does the speed of the gas molecules change?
22. What is the value of the product  $nR$  for in this simulation?

Set the temperature to 400 K.

23. For which value of the volume is the pressure 100 kPa?
24. For which value of the volume is the pressure 300 kPa? Use the ideal gas law to calculate the precise value and use the simulation to verify your answer.

## 5 – Find the number of moles.

A physicist performs an experiment to evaluate the number of moles of a gas inside a container. The container is kept at constant room temperature of 23°C and is built in such a way that the number of moles stays constant. The physicist changes the volume to different values and measures the corresponding absolute pressures. The table below shows the results of the experiment.

<i>V</i>	50 ml	45 ml	40 ml	35 ml	30 ml	25 ml
<i>P</i>	168 kPa	194 kPa	215 kPa	248 kPa	287 kPa	377 kPa

Make a plot of  $P$  vs  $1/V$ , force the intercept to zero and calculate the slope of the line.

If you plot  $P$  vs  $V$  the plot is not linear.

25. Value of the slope =

Assuming the gas obeys the ideal gas law, use the value of the slope to find the number of moles. Pay attention to using the correct units for all the quantities. For example the gas constant  $R$  has the value 8.314 if  $V$  is expressed in  $\text{m}^3$ ,  $P$  in Pascal and  $T$  in degrees Kelvin.

26. Number of moles  $n$  =