CHEM 361A - Lecture 2 Activity

Properties of Gases

In Class

1. The Ideal Gas Law

   (a) **Boyle's Law** relates pressure and volume for a fixed amount of an ideal gas. Upon performing an experiment where the pressure was measured of 1 mol of gas at 298 K while it was expanded from 5 L to 50 L gave the results shown in Figure 1. Is the relationship between pressure and volume proportional or inversely proportional?

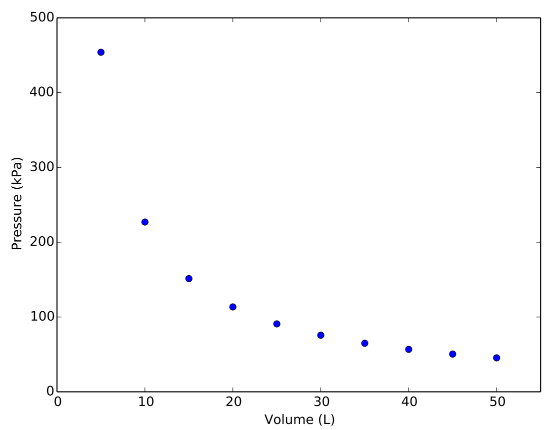

Figure 1: Results from an experiment where the pressure is measured of an ideal gas as it is expanded.

   (b) Write the relationship between pressure and volume using the proportional symbol ($\propto$)

   (c) Use the relationship from the previous question, to answer the following question: if you have a gas in a 1 L box at 100 kPa, and you expand the box to 2 L, what is the pressure of the gas in the expanded box?

   (d) **Charles' Law** relates the volume of an ideal gas to its temperature while holding its pressure constant. Upon performing an experiment where the volume was measured for 1 mol of gas at atmospheric pressure (101.3 kPa) while it was heated from 275 K to 335 K gave the results shown in Figure 2. Is the relationship between volume and temperature proportional or inversely proportional?

   (e) Write the relationship between volume and temperature using the proportional symbol ($\propto$)

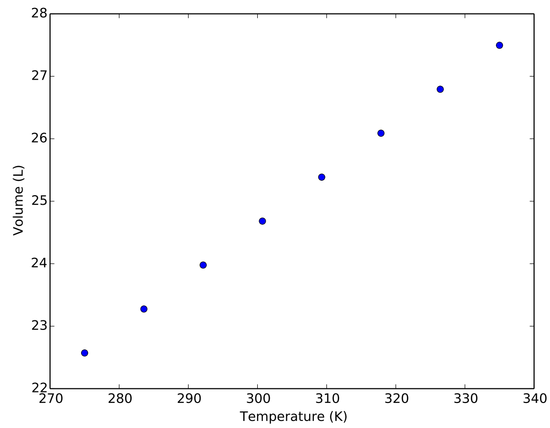

Figure 2: Results from an experiment where the pressure is measured of an ideal gas as it is expanded.

(f) Use the relationship from the previous question, to answer the following question: if you have a gas in a 1 L box at 293 K, and you heat the box to 363 K, what sized box would you need so that the gas has the same pressure?

(g) Extrapolate Charles' Law to absolute zero (0 K). Does Charles' Law apply here? Why?

(h) **Avagadro' Law** relates the volume of an ideal gas to the number of moles while holding its pressure and temperature constant. Upon performing an experiment where the volume was measured for a gas at 298 K and atmospheric pressure (101.3 kPa) while the number of moles of gas are increased from 1 to 10 moles gave the results shown in Figure 3. Is the relationship between volume and the number of moles proportional or inversely proportional?

(i) Write the relationship between volume and the number of moles using the proportional symbol ($\propto$)

(j) Use the relationship from the previous question, to answer the following question: if you have one mole of a gas in a 1 L box, and you then add another mole of gas, what sized box would you need so that the gas has the same pressure?

(k) For the previous problem, does the molar volume change when the extra mole of gas is added and the volume is changed? Why?

(l) Take the three $\propto$ statements you wrote for Boyle's Law, Charles' Law and Avagadro's Law and put them together. What are you missing so that you would get the ideal gas law?

2. Pretend that you have a box with three gases in it at 298 K. There is 1 mole of gas 1, 2 moles of gas 2, and 3 moles of gas 3. The partial pressure of gas 3 is 76.6 kPa. For this mixture calculate

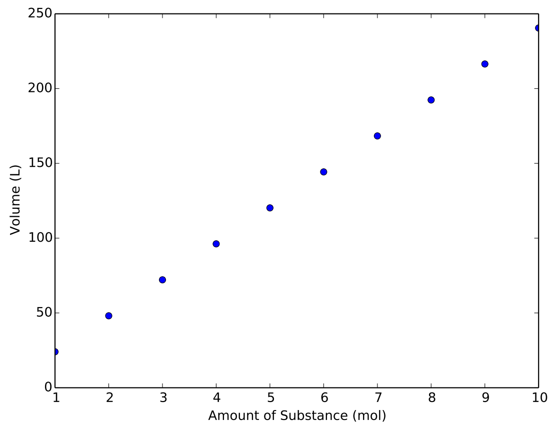

Figure 3: Results from an experiment where the pressure is measured of an ideal gas as it is expanded.

(a) the volume of the box ($V = 97.0$ L)

(b) the total pressure ($P_T = 153.2$ kPa)

3. The Ideal Gas Law is only an approximation for real gases. It exactly predicts their behavior at zero pressure and becomes less accurate as the pressure increases. Why?

4. Draw a table like the following and fill it in:

	Conditions where it can be used	Limitations	Benefits
Ideal Gas Law			
vdW Eqn of State			
Virial Eqn of State			

5. You have a gas which you would like to describe using the following equation of state:

$$p = \frac{nRT}{V} - g\left(\frac{n}{V}\right)^2 \quad \text{where: } g = 632.4 \text{ kPa L}^2 \text{ mol}^{-2}$$

(a) You have 5 moles of this gas in a 7 L container at 37°C. Compare the pressure using the provided equation of state, versus the van der Waals equation of state. Assuming that the van der Waals equation of state accurately quantifies the gas, is there a net attractive or repulsive interaction that the given equation of state fails to quantify? The van der Waals equation of state parameters for this gas are $a = 557.8$ kPa L^2 mol^{-2} and $b = 6.51 \times 10^{-2}$ L mol-1.

(b) Given your result above, would you increase or decrease the parameter g in order to match its result with the van der Waals equation of state?

Homework

6. Atmospheric pollution is a problem that has received much attention. Not all pollution, however, is from industrial sources. Volcanic eruptions can be a significant source of air pollution. The Kilauea volcano in Hawaii emits 250,000 kg of SO2 per day. If this gas is emitted at 800°C and 1.0 atm, what volume of gas is emitted in one day? ($V = 3.434 \times 10^8$ L)

7. Calculate the difference in pressure of 4.0 moles of ethane (C_2H_6) confined in a volume of 1.5 L at 300 K between the Ideal Gas Law and the van der Waals equation of state ($a_{C_2H_6} = 5.507$ atm L^2 mol^2 ; $b_{C_2H_6} = 6.51 \times 10^{-2}$ L mol^{-1}). Based on this difference, is there a net attractive or repulsive force between C_2H_6 molecules not captured by the Ideal Gas Law? (Attractive Difference of 2572 kPa)

8. In these exercises, you will explore the Maxwell Distribution of Speeds.

$$\rho(v)\ dv = 4\pi \left(\frac{M}{2\pi RT}\right)^{\frac{3}{2}} v^2 \exp\left(\frac{-Mv^2}{2RT}\right)\ dv$$

   (a) Confirm that the mean speed of molecules of molar mass M at a temperature T is equal to

$$\langle v \rangle = \left(\frac{8RT}{\pi M}\right)^{\frac{1}{2}}$$

   Hint: The mean speed can be calculated using

$$\langle v \rangle = \int_0^\infty v\ \rho(v)\ dv$$

   and the following integral will be useful

$$\int_0^\infty x^3 e^{-ax^2}\ dx = \frac{1}{2a^2}$$

   (b) Confirm that the root mean squared speed of molecules of molar mass M at a temperature T is equal to

$$v_{rms} = \sqrt{\langle v^2 \rangle} = \left(\frac{3RT}{M}\right)^{\frac{1}{2}}$$

   Hint: The root mean squared speed can be calculated using

$$v_{rms} = \sqrt{\langle v^2 \rangle} = \sqrt{\int_0^\infty v^2\ \rho(v)\ dv}$$

   and the following integral will be useful

$$\int_0^\infty x^4 e^{-ax^2}\ dx = \frac{3\sqrt{\pi}}{8a^{\frac{5}{2}}}$$

(c) Show that

$$\frac{\langle v \rangle}{v_{rms}} = \left(\frac{8}{3\pi}\right)^{\frac{1}{2}}$$