CH 102 Spring 2019
Discussion #3
Chapter 11

Student name____________________________ TA name________________________ Section_______________________

Things you should know when you finish the Discussion hand out:

- Gas Laws $P \cdot V_{gas} = n_{gas} \cdot R \cdot T$
  $T(K) = T(°C) + 273.15$
  $R = 8.314 \frac{J}{(mol \cdot K)} = 8.314 \frac{L \cdot kPA}{(mol \cdot K)} = 0.08206 \frac{L \cdot atm}{(mol \cdot K)} = 0.08314 \frac{L \cdot bar}{(mol \cdot K)}$
- Average molar kinetic energy $= \overline{E} = \frac{M \cdot u_{rms}^2}{2} = \frac{3}{2} R \cdot T$
- $u_{rms} = \sqrt{u_{avg}^2} = \sqrt{\frac{3 \cdot R \cdot T}{M}}$
- rate $= \frac{amount}{Time}$; rate $\propto$ velocity

1. A bicycle tire is filled with air to a pressure of 4 atm, at a temperature of 27°C. Riding the bike on asphalt on a hot day increased the temperature of the tire to 78°C. The volume of the tire has increased by 4.0%. Draw a picture of the tire before and after the ride, showing variables associated with the tire in each situation. *Hint: Find mathematical relationship between initial and final volume.*

   a. What is the new pressure in the bike tire? Do you need a new volume of the tire after the ride when solving for the new pressure?

   b. Can you determine the volume of the tire after the ride? If not, what other information do you need?

2. Air bags are activated when a severe impact causes a steel ball to compress a spring and electrically ignite a detonator cap. This action causes sodium azide (NaN_3) to decompose explosively according to the equation below:

$$NaN_3(s) \rightarrow Na(s) + N_2(g)$$

   What mass of sodium azide must be reacted to inflate an air bag to 100. L at 27°C and 1.00atm?

3. A 20 L stainless steel container was filled with 2 atm of H_2 gas and 3 atm of O_2 gas. A spark ignited the mixture, producing water. What is the pressure in the tank if the reaction runs at 25°C? What is the pressure in the tank if the reaction run at 125°C? *Hint: Think about the state of water at those temperatures.*

   a. How will liquid water affect the volume of the container and the pressure?

4. At STP, 1 L of Br_2 reacts with 3 L of F_2 to completion and produces 2 L of a product. What is the formula of the product? Assume that all substances are gases. *Hint: 1 mol of all ideal gasses occupy the same volume.*

5. A rigid 4.0 L container contains 0.20 mol of H_2 and 0.20 mol of O_2 at 300. K. Circle your answer to each of the following questions.
   a. On average, molecules of which gas hit the container walls more times per second?

      H_2 O_2 the same further information required

   b. On average, molecules of which gas hit the container walls with greater momentum?

      H_2 O_2 the same further information required

   c. On average, molecules of which gas hit the container walls with greater force?

      H_2 O_2 the same further information required

   d. On average, molecules of which gas contribute more to the total pressure?

      H_2 O_2 the same further information required

   e. What is the total pressure exerted on the walls of the container, in atm?

6. Which of the following combinations of conditions will a gas behave most ideally? Explain your choice.
   a. Low P and low T
   b. Low P and high T
   c. High P and high T
   d. High P and low T

7. Consider two identical cylinders, one containing 1.0 mole of He and the other containing 1.0 mole of N_2. The cylinder of nitrogen gas has a constant temperature of 77°C.

   a. Will He atoms need to be hotter or colder to have the same rms speed as N_2 gas? Why? *Hint: Think about this conceptually. Do not try to plug numbers in.*

   b. Calculate the temperature in K of the He such that it will have the same rms speed as the N_2 gas at 77°C . *Hint: You do not need to calculate the value of rms speed to solve this problem.*

   c. If both gases act ideally, circle which of the following must be true about the average kinetic energy, and gas pressure if both gases are at the same T? *Hint: What do pressure and force depend on?*

   $\bar{E}_{He} > \bar{E}_{N_2}$ $\bar{E}_{He} < \bar{E}_{N_2}$ $\bar{E}_{He} = \bar{E}_{N_2}$

   $P_{He} > P_{N2}$ $P_{He} < P_{N2}$ $P_{He} = P_{N2}$

   d. If identical holes opened in each cylinder, what will be true about the time for the gases to effuse out their cylinders if both gases are at the same T? Hint: faster means less time spend

   $time_{(He)} > time_{(N2)}$ $time_{(He)} < time_{(N2)}$ $time_{(He)} = time_{(N2)}$ More information needed

8. At 0°C and 1 bar = 100 kPa, the average speed of oxygen molecules is 460 m/s. When the pressure is lowered by half at 0°C, what will the average speed will be?

9. A sealed balloon is filled with 1 L of helium at 27°C and 1 atm. The balloon rises to a point in the atmosphere where the pressure is 0.3 atm and the temperature is -33°C. ($M = \frac{m \cdot R \cdot T}{V \cdot P} = \frac{\rho \cdot R \cdot T}{P}$)

   a. What is the density inside the balloon after the balloon rises?

   b. What is the density inside the balloon before it rises?

   c. What is the volume of the balloon at the end? Are we expecting for balloon to expand?

10. Methanol, CH_3OH, can be produced by the following balanced reaction: $CO(g) + 2H_2(g) \rightarrow CH_3OH(g)$. Hydrogen at SATP flows into a reactor at a rate of 12.5 L/min. Carbon monoxide at SATP flows into the reactor at a rate of 25 L/min. If 6.4 g of methanol is produced per minute, what is the percent yield of the reaction per minute? *Hint: solve considering that everything happened in 1 minute.*

(SATP: T=25°C; P = 1 bar = 100 kPa; $V_{(\text{of 1 mole of the gas})} = \frac{1 \cdot R \cdot T}{P} = 24.789 \text{ L} = 25 \text{ L}$)

11. At 20°C the average speed of oxygen molecules is 500 m/s. What will be the average speed of xenon atoms?

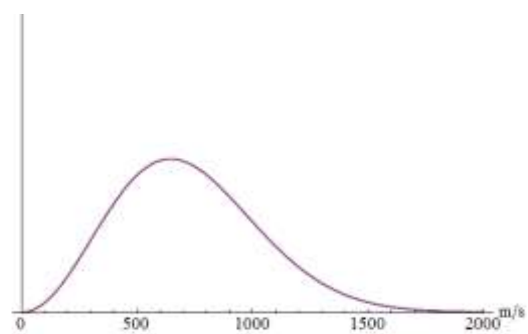
12. The unbalanced equation for combustion of ethane at 400. K is given below:

$$C_2H_6(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$$

When 4.0 mol of ethane and 20. mol of oxygen are combined in a rigid container at 400. K, the total pressure is 4.8 atm. A spark ignites the mixture, resulting in complete combustion. Calculate the final pressure at 400. K.

13. At a certain temperature, T_X, gas X (molar mass M_X) has an rms speed of 805 m/s. Derive an expression in terms of T_X for the temperature, T_Y, at which substance Y (molar mass M_Y) has the same rms speed. Write your expression in the box.

14. The graph shows the distribution of speeds of ozone, O_3, at 1200 K. Sketch on the graph the distribution of speeds of methane, CH_4, at 400 K.



15. A mixture of 1.0 g of hydrogen gas ($H_2(g)$) and 1.0 g of helium gas(He(g)) exerts a pressure of 0.50 atm. What is the partial pressure of each gas in the mixture?

$n_{total} = n_1 + n_2 + n_3$; $p_{total} = p_1 + p_2 + p_3 = (n_1 + n_2 + n_3)\frac{P \cdot V}{T}$; $\chi_1 = \frac{n_1}{n_{total}}$; $p_1 = \chi_1 \cdot p_{total}$

16. Hydrogen chloride gas is produced in a 100. L container according to the following reaction:

$$H_2 (g) + Cl_2 (g) \rightarrow 2 HCl (g)$$

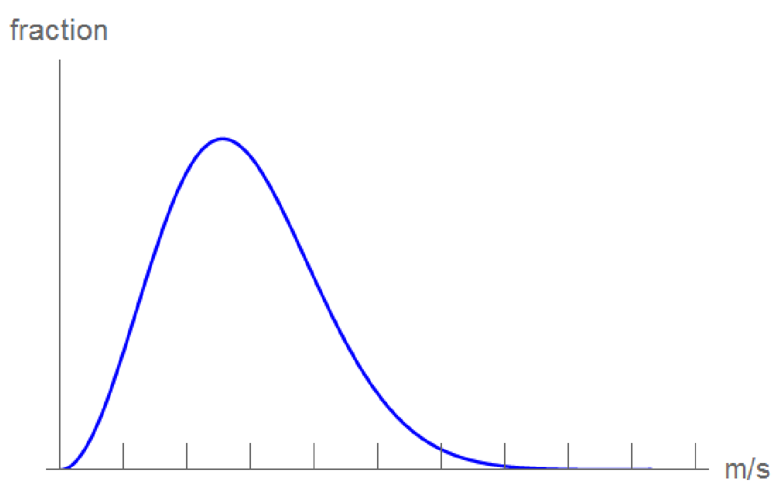
Initially 5.00 moles of H_2 and 3.00 moles of Cl_2 react. After the reaction is complete, the pressure in the reactor is 3.00 atm. Assuming that the process went to completion, what is the partial pressure (in atm) of all the gases in the container?

What is the percent of each gas in the mixture?

17. The Haber process is used to produce gaseous ammonia from gaseous N_2 and H_2. A 10 L reactor is charged with 28 g of N_2 and 3 g of H_2. After the reaction is complete, the pressure in the reactor is 3 atm. Assuming that the process went to completion, what is the partial pressure (in atm) of ammonia in the reactor?

18. A mixture of gases contains n_A moles of CH_4, n_B moles of C_2H_6, and n_C moles of C_3H_8. The total pressure is P_T. Derive an expression, in terms of only the variables listed in this problem, for the partial pressure of CH_4, P_A.

19. Polar stratospheric clouds (PSCs), which form at temperatures below −83°C, support chemical reactions whose products deplete gaseous ozone, O_3, in the Antarctic.
   a. Compute the rms speed of ozone at −83°C.
   b. On the graph at right, indicate by a vertical line the rms speed of ozone at −83°C,
   c. Add to the graph above a sketch of the distribution of speeds for oxygen, O_2, also at −83 °C.



20. Calcium dissolved in the ocean is used by marine organisms to form $CaCO_3(s)$ in skeletons and shells. When organisms die, their remains fall to the bottom. The amount of calcium carbonate that can dissolve in seawater depends on the pressure. This prevents the world's calcium from being tied up as insoluble $CaCO_3(s)$ at the bottom of the sea. At pressures of 414 atm, the shells slowly re-dissolve. Estimate the depth (in meters) where water exerts 414 atm of pressure **to one significant figure**. The density of sea water is 1030 $kg \cdot m^{-3}$ and force (F) = mass(m) x the acceleration of gravity(g) where g = 9.81 $m \cdot s^{-2}$. *Hint: P = F/A and A = V/h, 1atm = 101 kPa, 1 Pa 1 kg/(m·s²)*

Numerical Answers

1.
   a. 4.5 atm
   b. No; # of mol or V_1
2. 176 g
3. @ 25°C: 2 atm; @ 125°C: 4 atm
4. BrF_3
5.
   a. H_2
   b. O_2
   c. The same
   d. The same
   e. 2.5 atm
6. B
7.
   a. He colder; smaller so moving faster than N_2
   b. 50 K
   c. $\overline{E_{He}} = \overline{E_{N_2}}$; $P_{He} = P_{N2}$
   d. $time_{He} < time_{N2}$
8. 460 m/sec
9.
   a. 0.061 g/L
   b. 0.16 g/L
   c. 3 L
10. 80.%
11. 250 m/sec
12. 5.2 atm
13. $T_y = \frac{T_x \cdot M_y}{M_x}$
14. The same
15. H_2: 0.33 atm, 66%; He: 0.17 atm, 33%
16. H_2: 0.750 atm; HCl: 2.25 atm // H_2: 25%, HCl: 75%, Cl_2: 0%
17. 2 atm
18. $P_A = \frac{n_A}{(n_A + n_B + n_C)} \cdot P_T$
19. 314m/s; 385m/s
20. 4000m