Name: ____ Date: _____________________ CHEM 1A

Monday/Tuesday November 4 & 5, 2019 - Kinetic Model of Gases & Effusion and Diffusion (Chapter 5 Pt 2)

I. Recall & Warm-Up

1. What is the difference between **scientific theory** and **scientific law**?
   Law = what happens, Theory = why happens

2. Which gas is most dense at 1 atm and 25°C?
   (A) hydrogen cyanide (D) carbon monoxide
   (B) hydrogen sulfide (E) nitrogen dioxide
   (C) nitrogen monoxide
   Highest molar mass = highest density

3. Which of the following will have the greatest average kinetic energy? $KE_{ave} = 3/2RT$
   (a) 2.4-L of He at 1 atm and 25°C
   (b). 5.9-L of Ne at 2 atm and 20°C

Assumptions Needed for the Kinetic Theory of Gases

1. Volume of gas is small compared to traveling distance.
2. No attraction or repulsion (total energy of gas= KE)
3. Continuous random motion
4. Completely elastic collisions such that no gain or loss of kinetic energy during particle collision
5. KE(avg) is the same for any gas at a given temp and only depends on temp
   KE = 3/2kT

II. The Kinetic Model of Gases

4. The kinetic-molecular theory of gases does *not* assume that
   (A) gases are made up of tiny particles in constant chaotic motion.
   (B) gas particles are very small compared to the average distance between the particles.
   (C) gas particles collide with the walls of their container in elastic collisions.
   (D) the average velocity of gas particles is directly proportional to the absolute temperature.
   (E) All of these are correct.

Most Probable Velocity (u_mp)

u = sqrt(2RT/M)

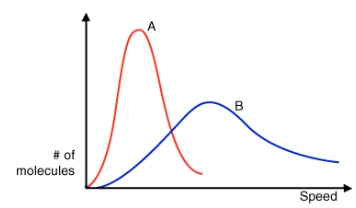
Average Velocity (u_ave)

u = sqrt(8RT/M)

Root Mean Square Velocity (u_rms)

u = sqrt(3RT/M)

5. The plots on the right represent the speed distribution for 1.0 L of oxygen at 300 K and 1000 K. Identify which temperature goes with each plot.



According to the average speed equation ⇒Uave = $\sqrt{\frac{8RT}{\pi M}}$ we can see the relationship between average speed and temperature: as T ↑ u_{avg} ↑since u_{avg} B > u_{avg} A ⇒ $T_B > T_A$ **Plot A ⇒ 300K and Plot B ⇒ 1000K**

6. Now the plots on the right represent the speed distribution for 1.0 L of He gas at 300 K and 1.0 L of Ar gas at 300 K. Identify which gas goes with each plot.

According to the average speed equation ⇒Uave = $\sqrt{\frac{8RT}{\pi M}}$we can see the relationship between average speed and molar mass⇒as molar mass ↑ u_{avg} ↓⇒since u_{avg} B > u_{avg} A ⇒ $M_B < M_A$ **Plot A ⇒ Ar and Plot B ⇒ He**

7. Calculate the average kinetic energy of CH_4 molecules at 0.°C. Report answer in J/mol.

According to Kinetic Theory, the average kinetic energy of gas molecules depends only on temperature.

KE = 3/2kT = 3/2(1.381 x 10^-23 J/K)(273K) = 5.66 x 10^-21J/molecule x 6.022x10^23/mol = **3.41 J/mol**.

8. Calculate the temperature at which the average velocity of Ar (g) equals the average velocity of Ne (g) at 25°C.

$u_{ave} = \sqrt{\frac{8RT}{\pi M}} \Rightarrow u_{ave}\ Ar = u_{ave}\ Ne \quad \Rightarrow \quad \sqrt{\frac{8RT_{Ar}}{\pi M_{Ar}}} = \sqrt{\frac{8RT_{Ne}}{\pi M_{Ne}}} \Rightarrow$ 8, R, and π constant

$\frac{T_{Ar}}{M_{Ar}} = \frac{T_{Ne}}{M_{Ne}} \Rightarrow \quad T_{Ar} = \frac{M_{Ar}T_{Ne}}{M_{Ne}} \Rightarrow T_{Ar} = \frac{(298K)(39.95\ g/mol)}{(20.18\ g/mol)} \Rightarrow T = 590\ K$ or 317°C

9. A plot of the Maxwell distribution against speed for different molecules shows that
A) heavy molecules have a higher average speed.
B) light molecules have a very narrow range of speeds.
C) heavy molecules have a wide range of speeds.
D) light molecules have a lower average speed.
E) heavy molecules travel with speeds close to their average values.

Diffusion – The spreading of one substance through another substance. $\frac{d_A}{d_B} = \sqrt{\frac{M_B}{M_A}}$

Effusion – The escape of a substance (particularly a gas) through a small hole.

Graham's Law of Effusion

$\frac{Rate_A}{Rate_B} = \sqrt{\frac{M_B}{M_A}}$ ** $\frac{time_B}{time_A} = \sqrt{\frac{M_B}{M_A}}$ **

If the numbers of particles are the same then**

III. Effusion and Diffusion

10. It takes 12 seconds for 8 mL of hydrogen gas to effuse through a porous barrier at STP. How long will it take for the same volume of carbon dioxide to effuse at STP?

$\frac{time_{CO2}}{time_{H2}} = \sqrt{\frac{M_{CO2}}{M_{H2}}} \Rightarrow \quad time_{CO2} = time_{H2}\sqrt{\frac{M_{CO2}}{M_{H2}}} \Rightarrow time_{CO2} = (12\ s)\sqrt{\frac{44.01 g/mol}{2.016 g/mol}} \Rightarrow time_{CO2} = 56\ s$

11. The effusion rate of H_2 gas is 6.45 times faster than that of a certain noble gas (both gases are at the same temperature). What is the noble gas?

Molar mass can be used to identify $\Rightarrow \quad \frac{rate_{H2}}{rate_{unk}} = \sqrt{\frac{M_{unk}}{M_{H2}}} \Rightarrow M_{unk} = M_{H2}\sqrt{\left(\frac{rate_{H2}}{rate_{unk}}\right)}$

$M_{unk} = 2.016\ g/mol\ \sqrt{6.45} \Rightarrow M_{unk} = 83.87\ g/mol \Rightarrow$ Unknown gas is Kr

12. The following experiment was carried out using a newly synthesized chlorofluorocarbon. Exactly 50 mL of the gas effused through a porous barrier in 157 s. The same volume of argon effused in 76 s under the same conditions. Which compound is the chlorofluorocarbon?
(A) $C_2Cl_4F_2$ (B) C_2ClF_5 (C) $C_2Cl_2F_4$ (D) C_2Cl_5F (E) $C_2Cl_3F_3$

$\frac{Rate_A}{Rate_B} = \sqrt{\frac{M_B}{M_A}} \quad \frac{time_x}{time_{Ar}} = \sqrt{\frac{M_x}{M_{Ar}}} \quad \frac{157s}{76s} = \sqrt{\frac{M_x}{39.9\ g/mol}}$ **Mx = 170g/mol =** $C_2Cl_2F_4$

13. Order the following according to increasing rate of effusion: F_2, Cl_2, NO, NO_2, CH_4

Larger mass = slower rate of diffusion, order heaviest to lightest $Cl_2 < NO_2 < F_2 < NO < CH_4$

14. Determine if each of the following statements are true or false:

a. Gases tend to behave more ideally at high temperatures and pressures
False – gases behave more ideally at high temperatures and low pressures

b. CO_2 and N_2O_4 gas have the same average kinetic energy at STP
True – KE ave = 3/2 RT – if both gases are at the same temperature they will have the same average KE

c. The distance between gas particles is much larger than the size of the gas particles is one of the assumptions of kinetic molecular theory True

d. 1 mol of CO at 1 atm and 25 °C has a greater collision frequency than 1 mol of N_2 at 0.9 atm and 25 °C.
True– collision frequency is proportional to P and T but inversely proportional to molar mass

e. In the van der Waals equation the *b* value increases as the forces between the gas particles gets stronger.
False – the b value is directly proportional to the size of the gas particles – whereas the a value in the VDW equation is directly proportional to the attractive forces