CH1020 Answers to Practice Problems for KMT, Effusion, Diffusion, Van der Walls equation

1. Suppose you have two 1-L flasks, one containing N_2 at STP, the other containing CH_4 at STP. How do these systems compare with respect to
   a. number of molecules
   b. density
   c. average kinetic energy
   d. rate of effusion through a pinhole leak?

   a. They have the same number of molecules (equal volumes of gases at the same T and P contain equal number of molecules)
   b. N_2 is more dense because it has the larger molar mass. Since the volumes of the samples and the number of molecules are equal, the gas with the larger molar mass will have the greater density.
   c. The average kinetic energies are equal
   d. CH_4 will effuse faster. The lighter the gas molecules, the faster they will effuse (Graham's law)

2. Vessel A contains CO_2 gas at 0^oC and 1 atm. Vessel B contains HCl gas at 20^oC and 0.5 atm. The two vessels have the same volume.
   a. which vessel contains more molecules?
   b. Which contains more mass?
   c. In which vessel is the average kinetic energy of molecules higher?
   d. In which vessel is the rms speed of molecules higher?

   a. n α P/T (V/R is the same for A and B). Since P is greater and T is smaller for vessel A, it has more molecules.
   b. Since vessel A has more molecules and the molar mass of CO_2 is greater than the molar mass of HCl, vessel A contains more mass.
   c. Vessel B is at a higher temperature so the average kinetic energy of its molecules is higher.
   d. The two factors that affect rms speed are temperature and molar mass. Since the molecules in Vessel B have smaller molar mass and higher temperature, they have greater rms speed

3. What change or changes in the state of a gas bring about each of the following effects?
   a. the number of impacts per unit time on a given container wall increases.
   b. The average energy of impact of molecules with the wall of the container decreases
   c. The average distance between gas molecules increases
   d. The average speed of molecules in the gas mixture is increased

   a. increase in temp. at constant V, decrease in V, increase in P
   b. Decrease in temperature
   c. Increase in volume
   d. Increase in temperature

4. Indicate which of the following statements regarding kinetic molecular theory of gases are correct. For those that are false, formulate a correct version of the statement
   a. the average kinetic energy of a collection of gas molecules at a given temperature is proportional to root of molar mass.
   b. The gas molecules are assumed to exert no forces on each other
   c. All the molecules of a gas at a given temperature have the same kinetic energy
   d. The volume of the gas molecules is negligible in comparison to the total volume in which the gas is contained.

   a. false. The average kinetic energy per molecule in a collision of gas molecules is the same for all gases at the same T
   b. True
   c. False. The molecules in a gas sample at a given temperature exhibit a distribution of kinetic energy
   d. True.

5. Consider a 1.0 L container of neon gas at STP. Will the average kinetic energy, average velocity, and frequency of collisions of gas molecules with the walls of the container increase, decrease, or remain the same under each of the following conditions?
   a. the temperature is increased to 100^{o}C
   b. the temperature is decreased to –50^{o}C
   c. the volume is decreased to 0.5 L
   d. the number of moles of neon is doubled

   Average kinetic energy and average velocity depend on temperature. As temperature increases, both average kinetic energy and average velocity increase. At constant temperature, both average kinetic energy and average velocity are constant. The collision frequency is proportional to the average velocity (as velocity increases it takes less time to move to the next collision) and to the quantity n/V (as molecules per volume increase, collision frequency increases.
   a. average KE increases, average velocity increases, and collision frequency increases
   b. average KE decreases, average velocity decreases, and collision frequency decreases
   c. average KE same, average velocity same, and collision frequency increases
   d. average KE same, average velocity same, and collision frequency increases

6. Consider separate 1.0 L gaseous samples of H_2, Xe, Cl_2 and O_2 all at STP
   a. rank the gases in order of increasing average kinetic energy
   b. rank the gases in order of increasing average velocity
   c. How can separate 1.0-L samples of O_2 and H_2 each have the same average velocity?

   a. All gases have the same kinetic energy since they are all at the same temperature

   b. At constant temperature, the lighter the gas molecule, the faster the average velocity: $Xe < Cl_2 < O_2 < H_2$

   c. At constant T, the lighter H_2 molecules have a faster average velocity than the heavier O_2 molecules. As temperature increases, the average velocity of the gas molecules increases. Separate samples of H_2 and O_2 can only have the same average velocities if the temperature of the O_2 sample is greater than the temperature of the H_2 sample.

7. Place the following gases in order of increasing molecular speed at 300 K: CO_2, N_2O, HF, F_2, H_2. Calculate and compare the rms speeds of H_2 and CO_2 at 300 K.
   $CO_2 = N_2O < F_2 < HF < H_2$
   u_{rms} ***for hydrogen*** $= 1.92 \times 10^3$ m/s
   u_{rms} ***for carbon dioxide*** $= 4.12 \times 10^2$ m/s

8. Calculate the average kinetic energy of the N_2 gas at 273 K and 546 K
   KE at 273 K $= 3.40 \times 10^3$ ***J/mol;*** ***KE at 546 K*** $= 6.81 \times 10^3$ ***J/mol***

9. Calculate the root mean square velocity of the CH_4 and N_2 molecules at 273 K and 546 K
   For CH_4 at 273 K = 652 m/s at 546 K = 921 m/s
   For N_2 at 273 K = 493 m/s at 546 K = 697 m/s

10. The rate of effusion of a particular gas was measured and found to be 24.0 mL/min. Under the same conditions, the rate of effusion of pure methane (CH_4) gas is 47.8 mL/min. What is the molar mass of the unknown gas?

    63.7 g/mol

11. It took 4.5 minutes for 1.0 L helium to effuse through a porous barrier. How long will it take for 1.0 L Cl_2 gas to effuse under identical conditions?

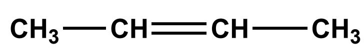
    19 minutes

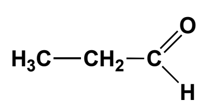
12. Under what experimental conditions of temperature and pressure do gases usually behave non-ideally? What two properties or characteristics of gas molecules cause them to behave ideally?
    Non ideal gas behavior is observed at very high pressures and / or low temperatures
    The real volumes of gas molecules and attractive intermolecular forces between molecules cause gases to behave non ideally.

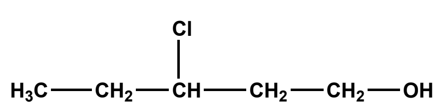
13. Calculate the pressure exerted by 0.5000 mol N_2 in a 1.0000-L container at 25°C
    a. using the ideal gas law ***12.24 atm***
    b. using the Van der Waals equation ***12.13 atm***
    c. compare the results. ***Ideal gas law is high by 0.11 atm or 0.91 %***

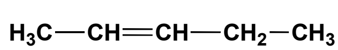
14. Calculate the pressure exerted by 0.5000 mol N_2 in a 10.0000-L container at 25°C
    a. using the ideal gas law ***1.224 atm***
    b. using the Van der Waals equation ***1.223 atm***
    c. compare the results. ***Results agree to ± 0.001 atm (0.08%)***
    d. Compare the results with those in Exercise 13. ***In Exercise 13, the pressure is relatively high and there is a significant disagreement. In Exercise 14, the pressure is around 1 atm, and both gas law equations show better agreement. The ideal gas law holds best at relatively low pressures.***

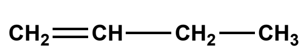
15 . Draw the structures for the following compounds (condensed structural formula):

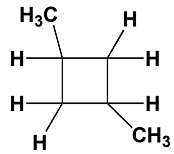
a). 2-butene 

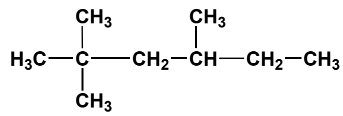
b). propanal 

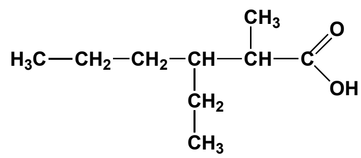
c). 3-chloro, 1-pentanol 

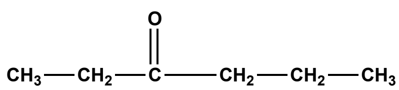
d). 2-pentene 

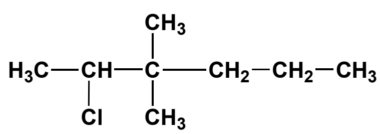
e). 1-butene 

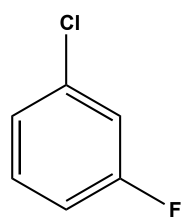
g). 1,3 dimethyl cyclobutane 

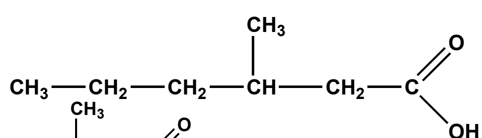
h). 2,2,4 trimethylhexane 

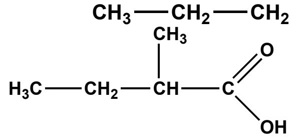
i). 2-methyl-3-ethyl hexanoic acid 

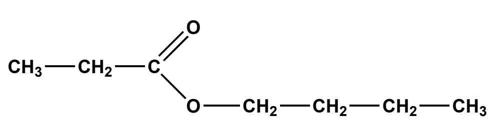
j). 3-hexanone 

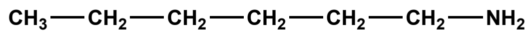
k). 2-chloro-3,3-dimethyl hexane 

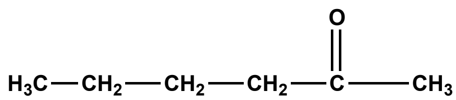
l). 1-chloro-3-fluorobenzene 

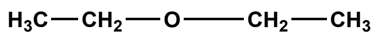
n). 3-methyl hexanoic acid 

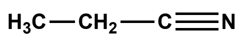
o). 2-methyl butanoic acid 

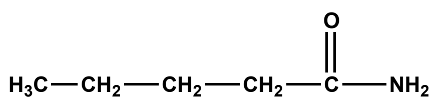
p). butyl propanoate 

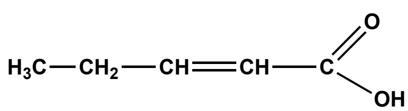
q). hexyl amine 

r). 2-hexanone 

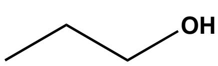
s). diethyl ether 

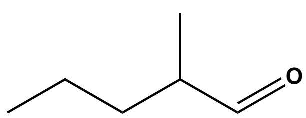
t). propane nitrile 

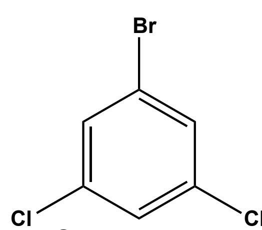
u). pentanamide 

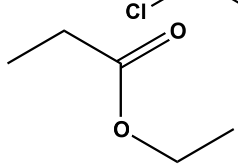
v). 2-pentenoic acid 

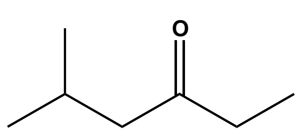
16. Draw the structures for the following compounds (carbon skeleton structure)

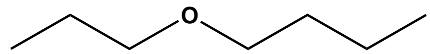
a). propanol 

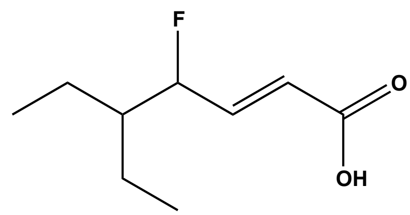
b). 2-methyl pentanal 

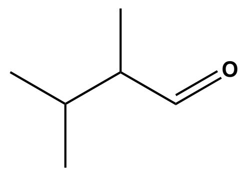
c). 1-bromo-3,5-dichlorobenzene 

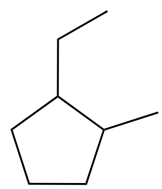
d). ethyl propanoate 

e). 5-methyl 3-hexanone 

f). butyl propyl ether 

g). 5-ethyl,4-fluoro, 2-heptenoic acid 

h). 2,3 dimethyl butanal 

i). 1-ethyl, 2-methyl cyclopentane 

j). pentanamide